SRBAVG: It's Time to Archive CERES Next-Generation Monthly Means

D. Doelling, D. Keyes
AS&M

D. Young
NASA Langley Research Center

C. Nguyen, R. Raju, J. Boghosian, T. Caldwell
SAIC

Fourth CERES-II Science Team Meeting
Hampton, VA, November 1-3, 2005

…with Special Thank to

B. Wielicki, T. Wong, T. Charlock, P. Minnis, D. Kratz
NASA Langley Research Center

N. Loeb, S. Kato
Hampton University

F. Rose, D. Rutan, M. Nordeen
AS&M

Outline

- What is SRBAVG?
- Product improvement
- Validation results
- A taste of the data
- Summary
- Archival Plans

CERES Temporal Interpolation and Spatial Averaging (TISA)

Goals

- Produce climate quality monthly means
  - Must maintain CERES instrument calibration
- Eliminate temporal sampling errors
- Retain consistency among TOA fluxes, cloud properties and surface fluxes

SRBAVG is the new CERES gridded monthly product

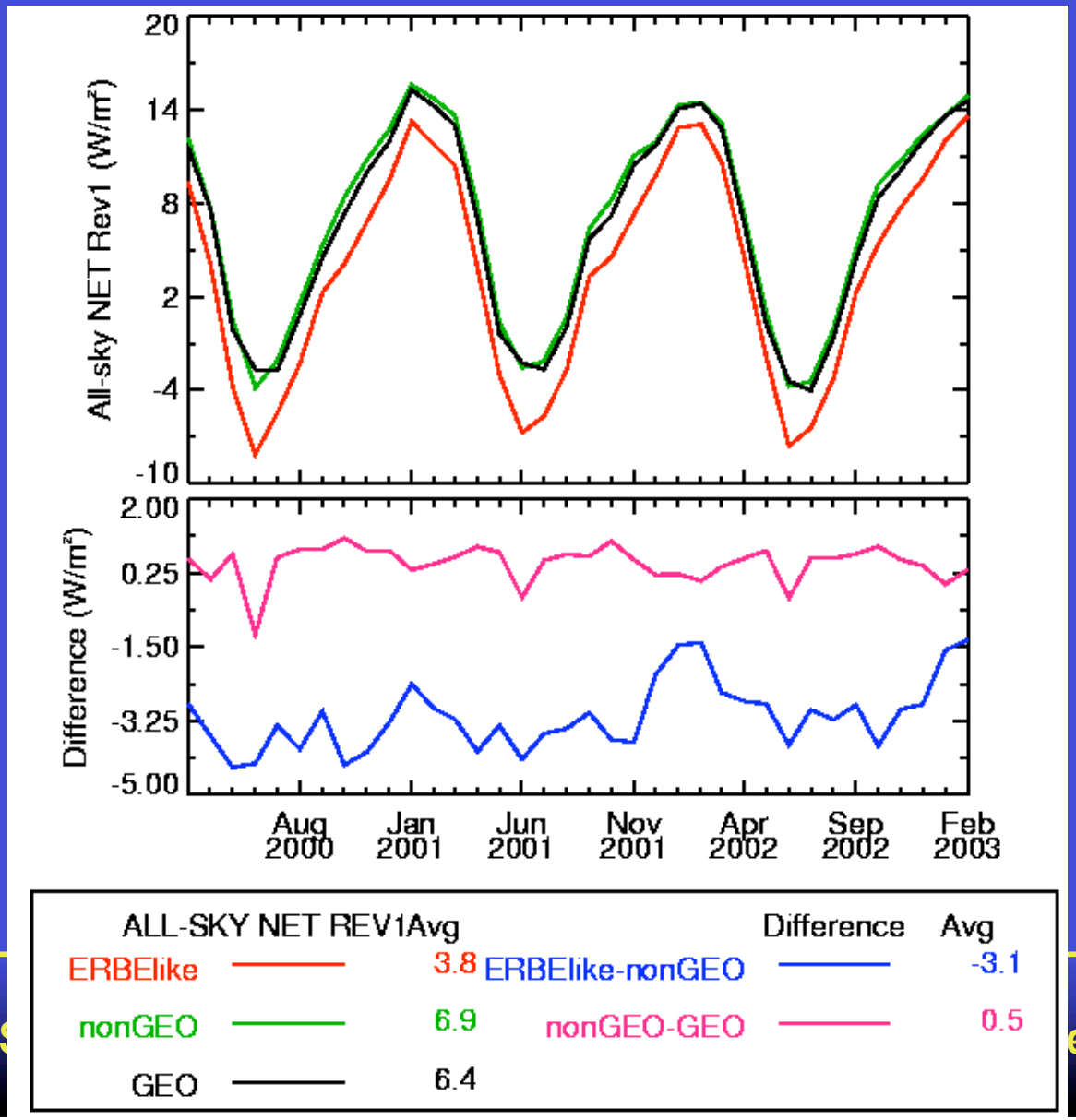
- We are ready to run 5 years of CERES Terra monthly means
- Validation results demonstrate robustness of interpolation
- Product details
  - Takes advantage of improved CERES fluxes
  - Uses improved temporal interpolation to remove sampling effects
  - 1.0° grid
  - TOA and surface fluxes
  - Detailed cloud properties
  - Product contains GEO and nonGEO monthly means

Why Now?

- Product delayed by ~18 months
  - Main cause was the concern over the ~5 W/m^2 global net flux imbalance
- All major aspects of the interpolation process have been studied to identify potential issues
  - GEO imager calibration
  - GEO cloud retrievals
  - Narrowband-Broadband conversion
  - ADMs and directional models
  - Twilight correction
  - GEO-CERES Normalization
- All of the above have been improved to eliminate biases
- So, what does the global net flux look like?……..

Global TOA Net Flux Comparison

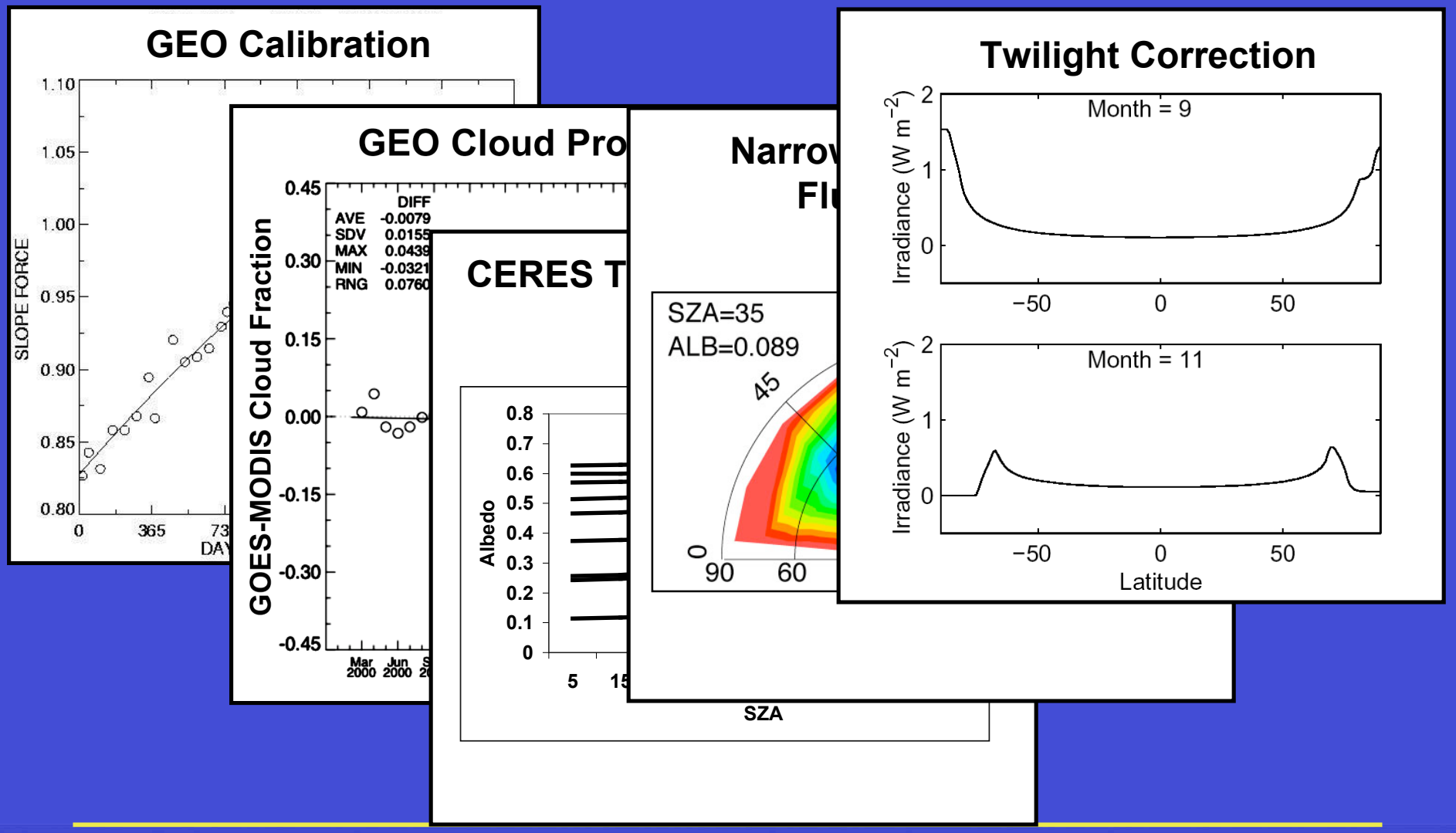
Ed2 SRBAVG REV1 March 2000 - February 2003



Why is the Bias still there?

- Bruce will address after this talk.
- We have studied the potential biases from the TISA algorithms
  - We now have confidence that the remaining flux imbalance is not caused by our TISA methods

Previous Improvements



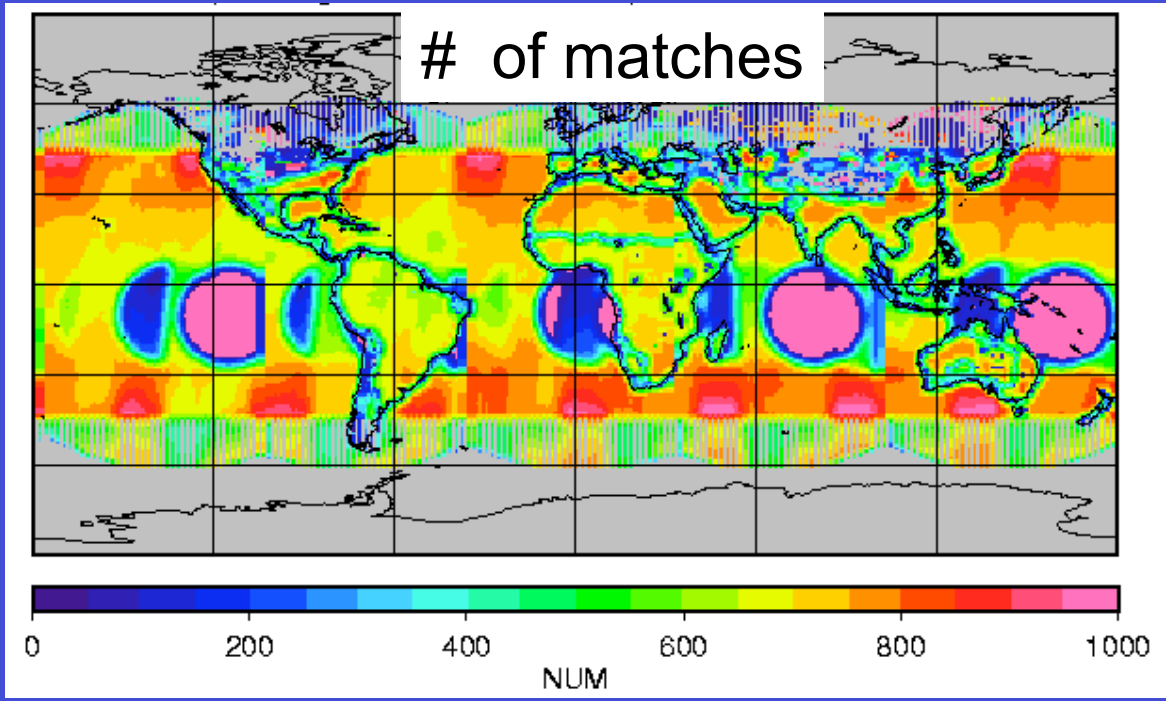
GEO-CERES Normalization

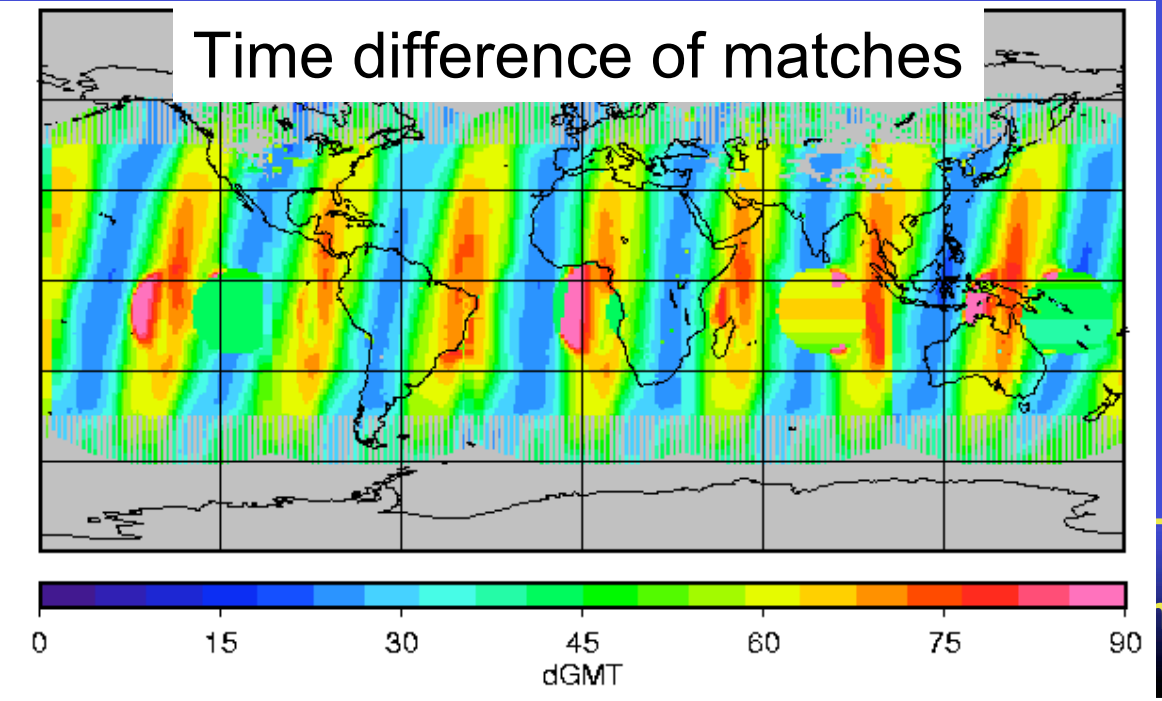
- There is still residual error in BB estimates from NB
  - 10-15% SW
  - 3-5% LW
- GEO time series of BB fluxes are normalized to CERES observations
- Original method used regional instantaneous normalization
  - In SW, this can lead to significant instantaneous errors
  - Still employed by LW
- New method uses 5°x5° regional monthly normalization
  - Improved dynamic range (uses slope and intercept)
  - Helps to reduce regional NB-BB errors

SW GEO Regional Normalization

- GEO clear-sky albedos are replaced with CERES
  - Land spectral differences are difficult to account for in GEO
  - No day to day variation in the clear-sky albedo
- Snow regions use the non-GEO method
  - GEO cloud properties over snow are suspect
  - Bright surfaces have little diurnal variation
- Perform regressions of GEO-derived and CERES matched SW fluxes
  - Slope and offset used to account for GEO visible calibration inadequacies and regional NB to BB variability
  - 5x5 surrounding regions and matches within 90 minutes
  - Regions are limited to GEO-satellite, and GEO-type
  - No glint matches are used
  - Regions with insufficient matches use 5° zonal regions

Jan01

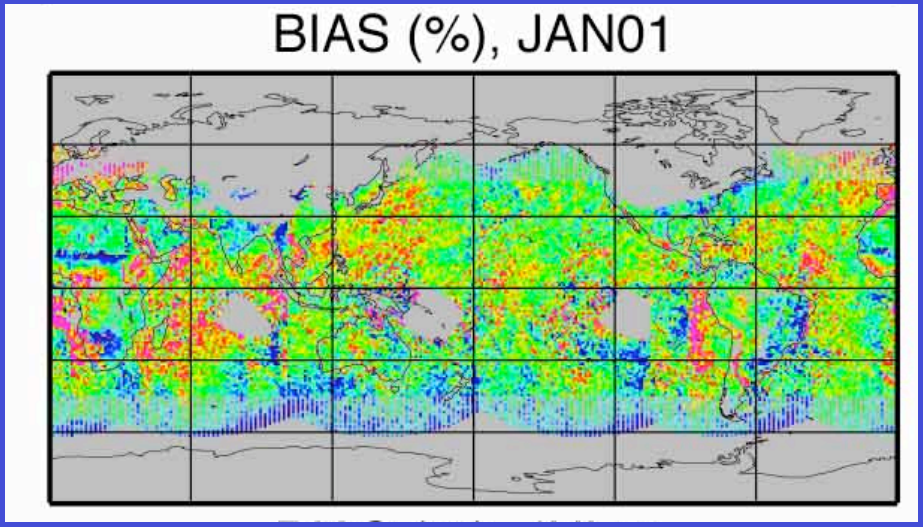

# of matches
0
200
400
600
800
1000
NUM


Time difference of matches
0
15
30
45
60
75
90
dGMT

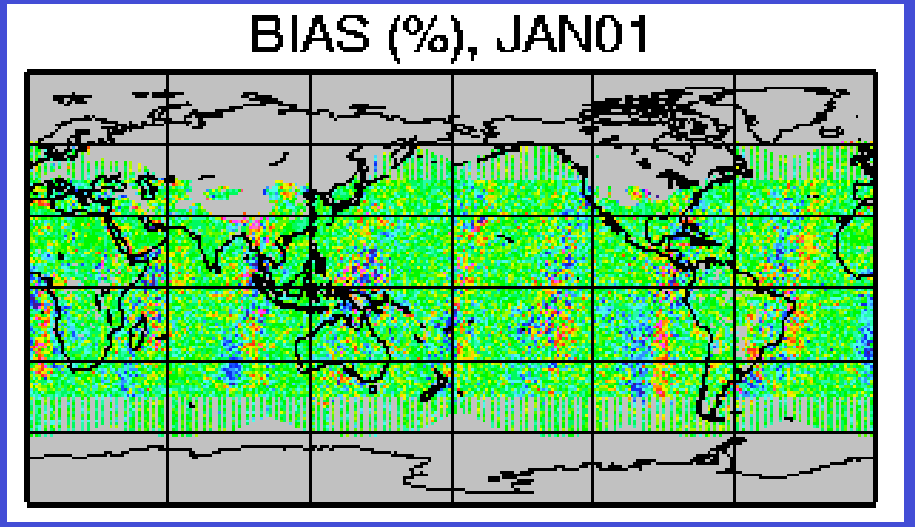
Regional SW biases (GEO - CERES) Jan01

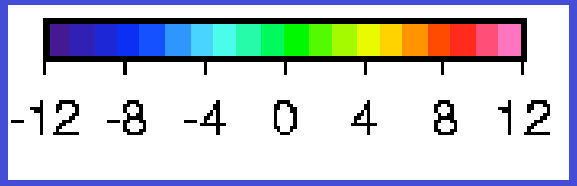
matched within a hour

Before



After

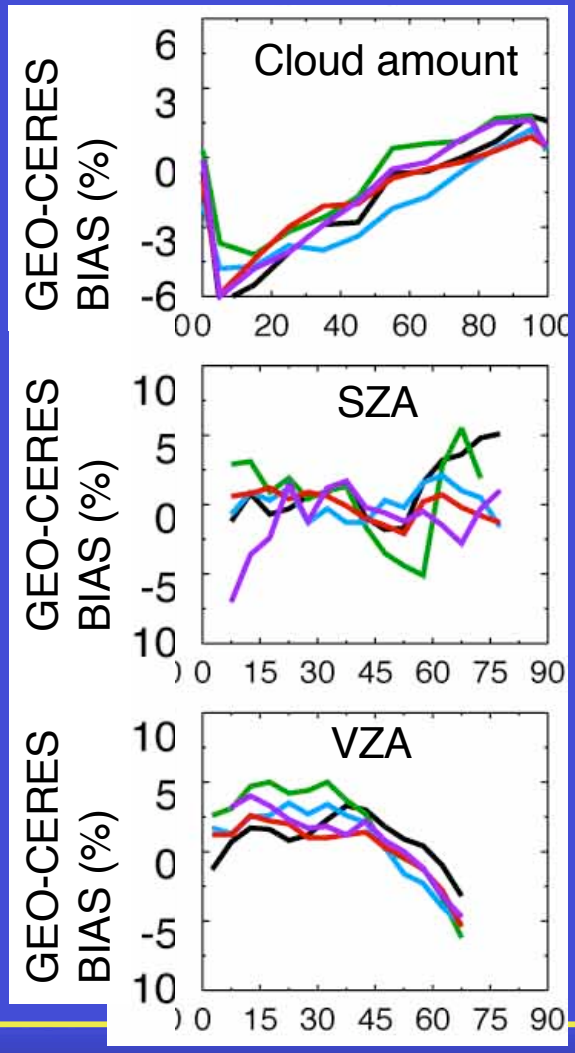




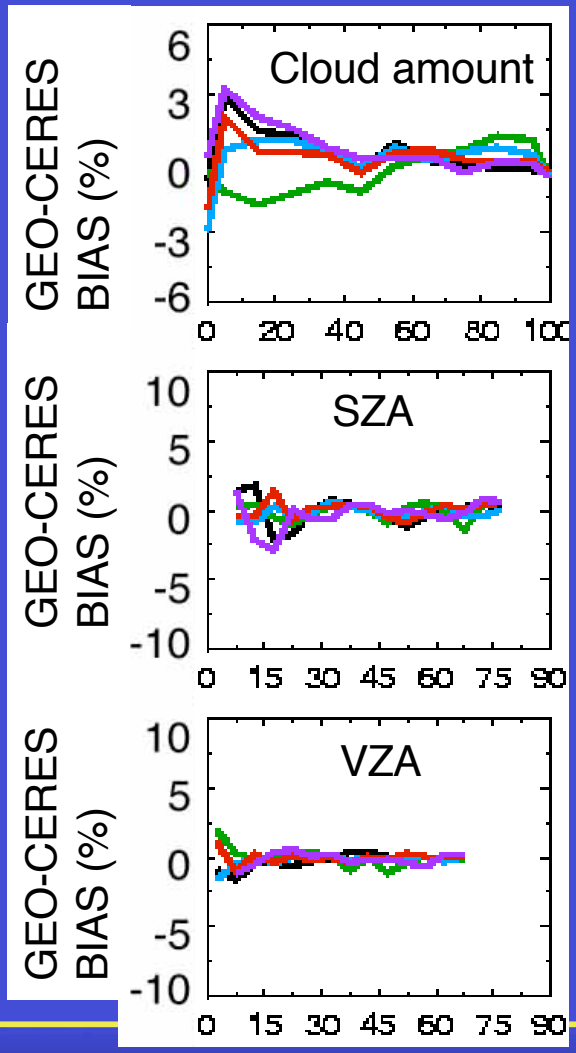
(%)

SW GEO-CERES Ocean Biases for Jan01

Before



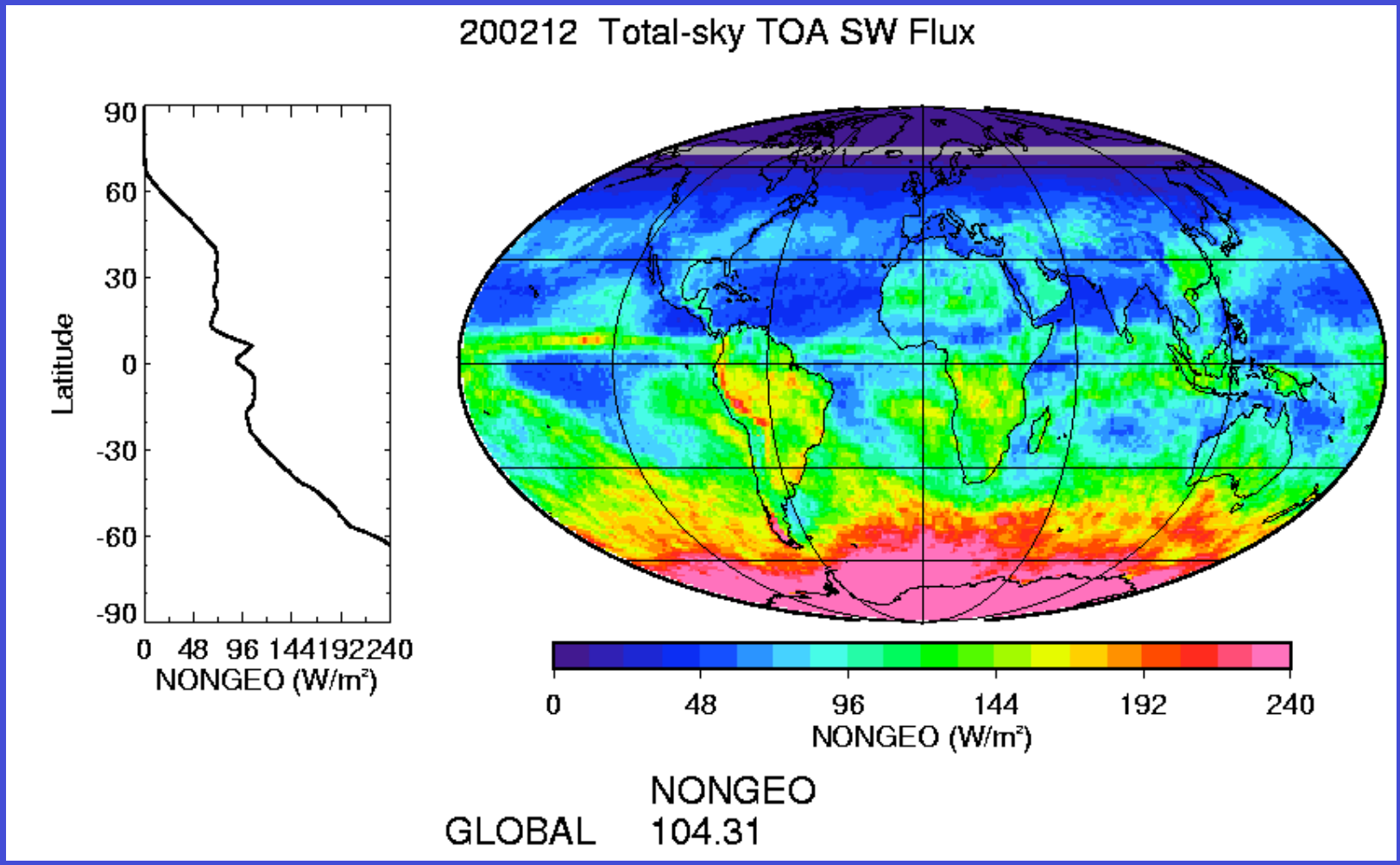
After



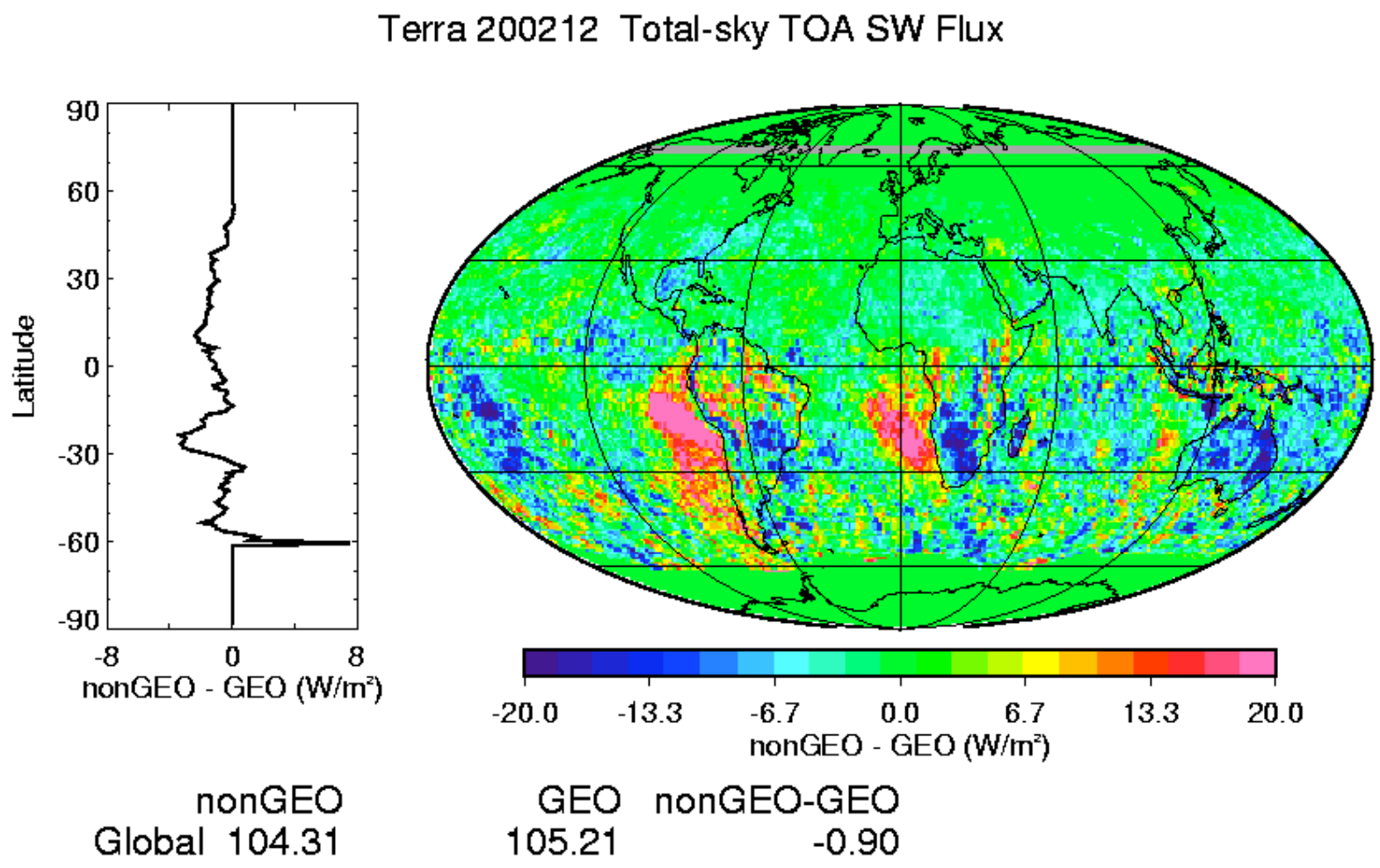
MET-7 MET-5 GMS-5 GOES-10 GOES-8

CERES

SRBAVG results
Dec 2002 GEO SW monthly mean

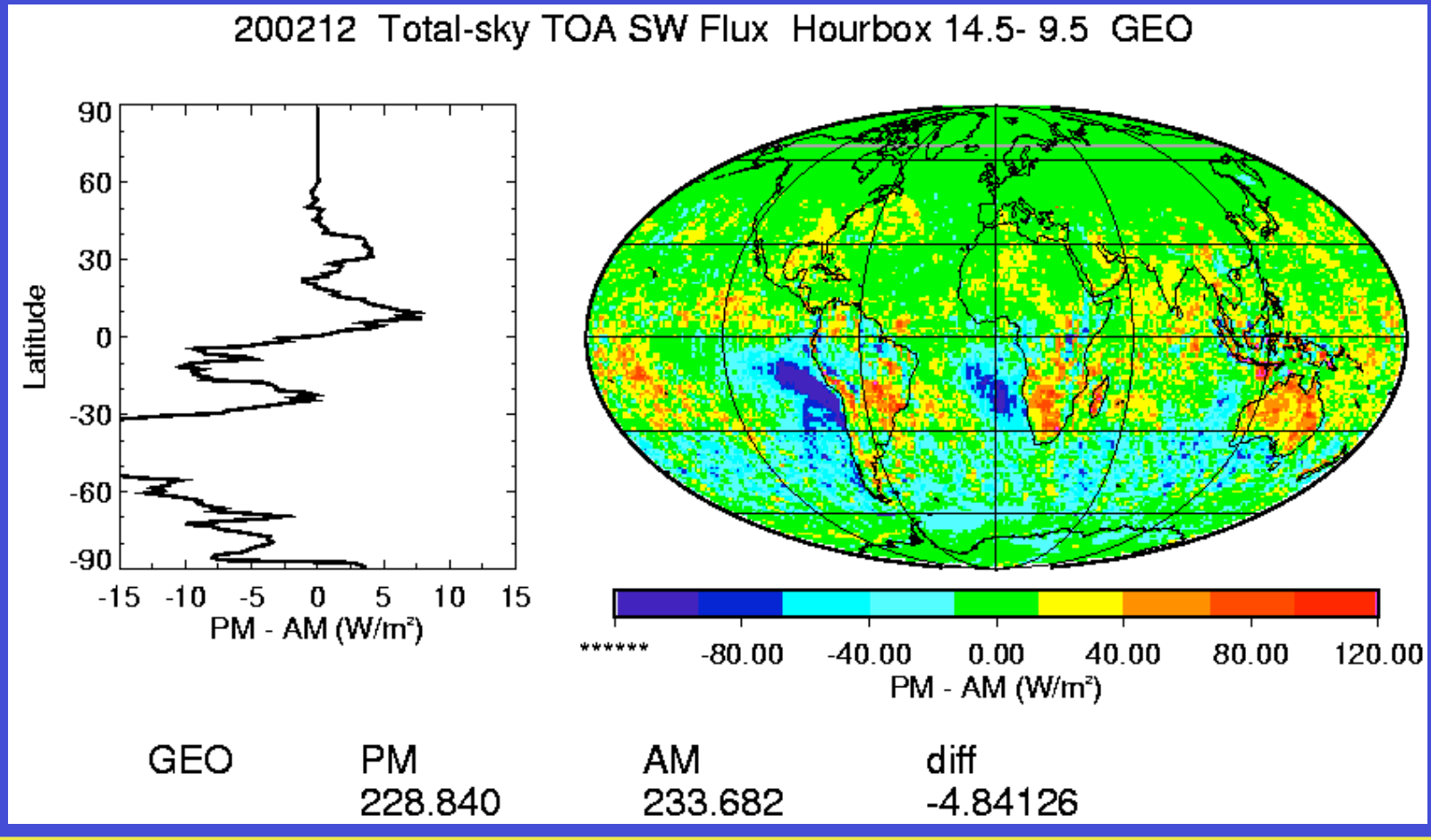


SRBAVG results
Dec 2002 nonGEO - GEO SW

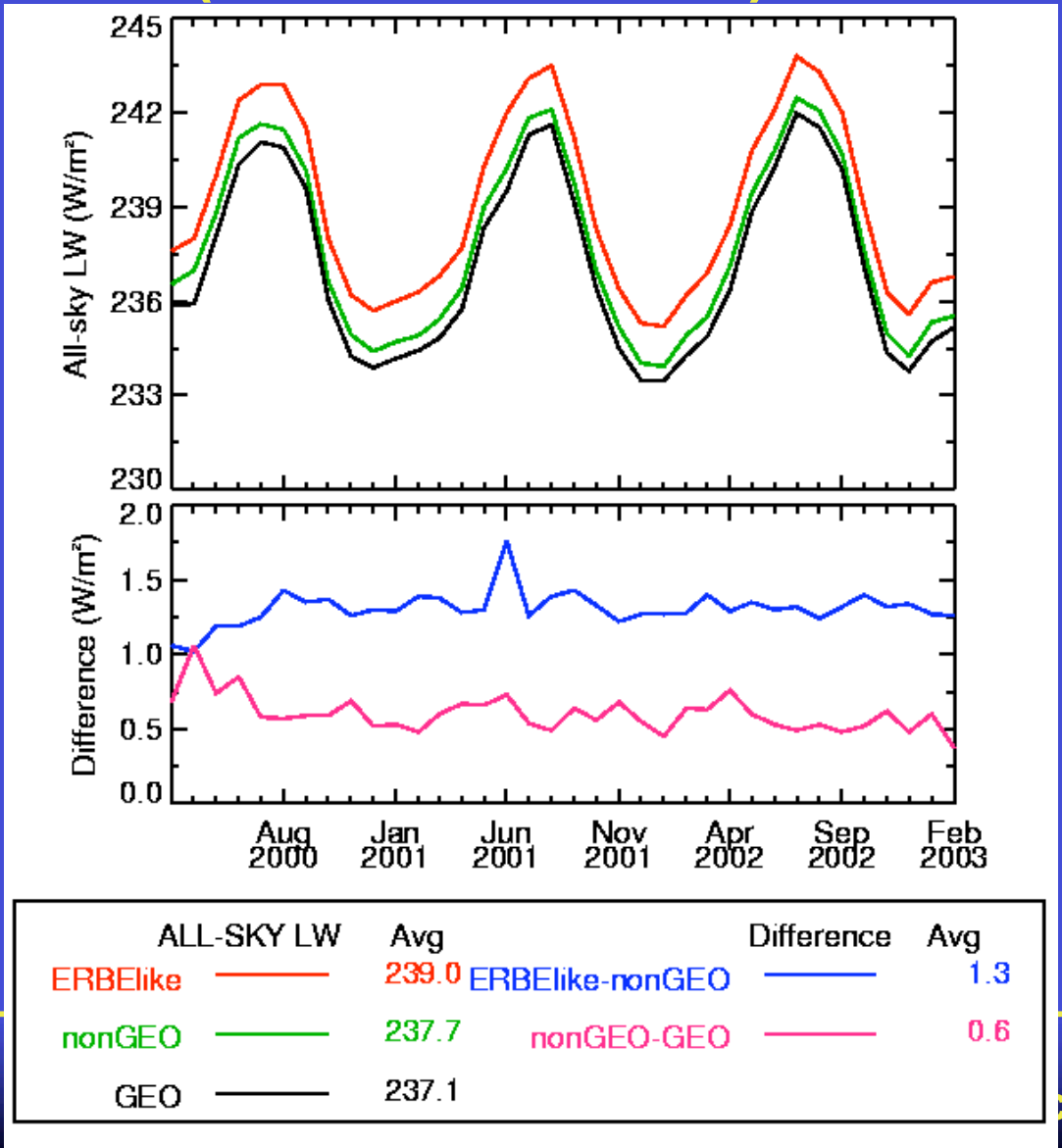


	nonGEO	GEO	nonGEO-GEO
Global	104.31	105.21	-0.90

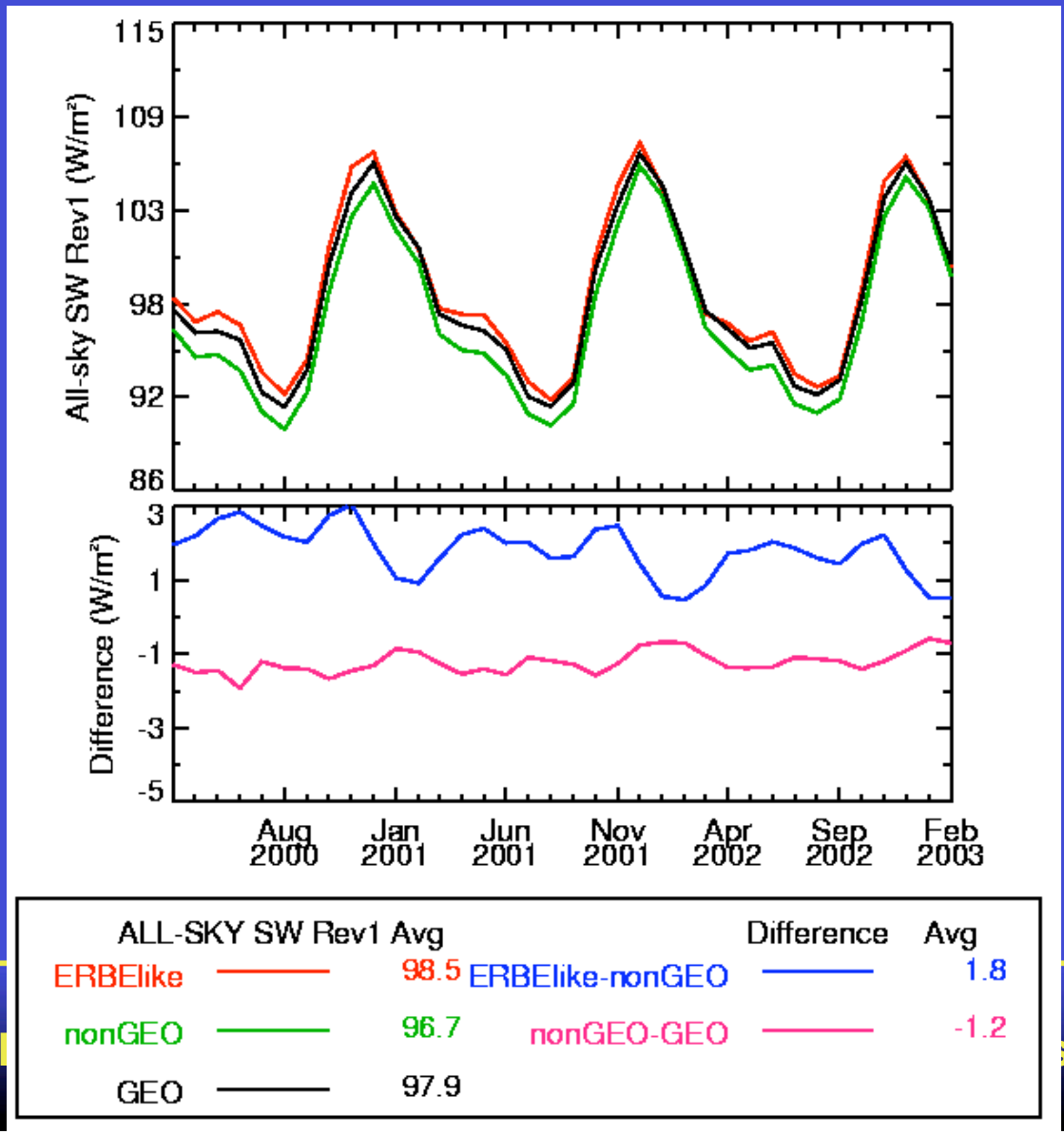
SRBAVG results
Dec 2002 GEO SW
2:30PM-9:30AM



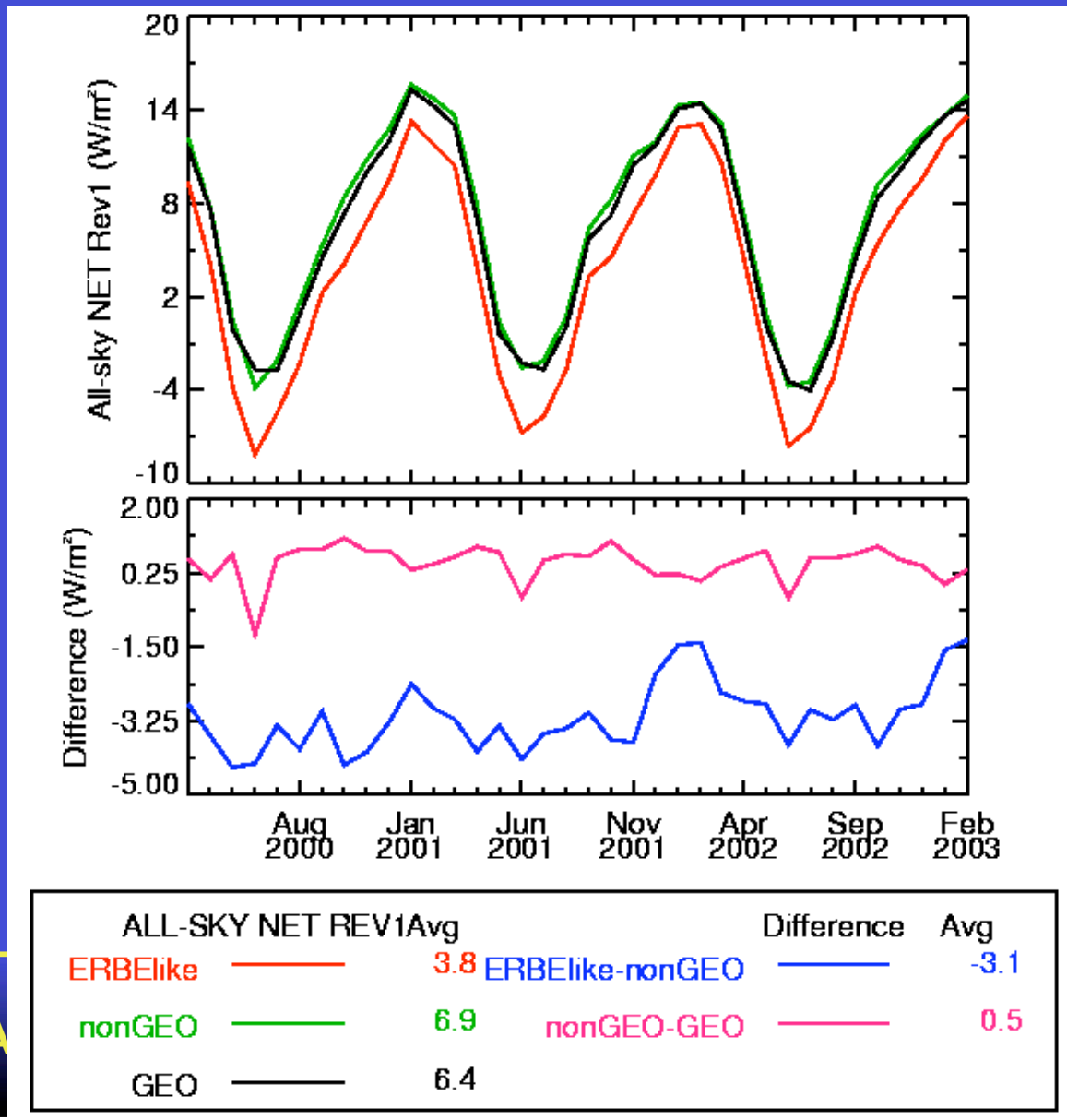
Global All-sky Longwave (Mar00 to Feb03)



Global All-sky Shortwave (REV 1) (Mar00 to Feb03)



Global All-sky Net (REV 1) (Mar00 to Feb03)



3 Year Global Mean TOA Fluxes

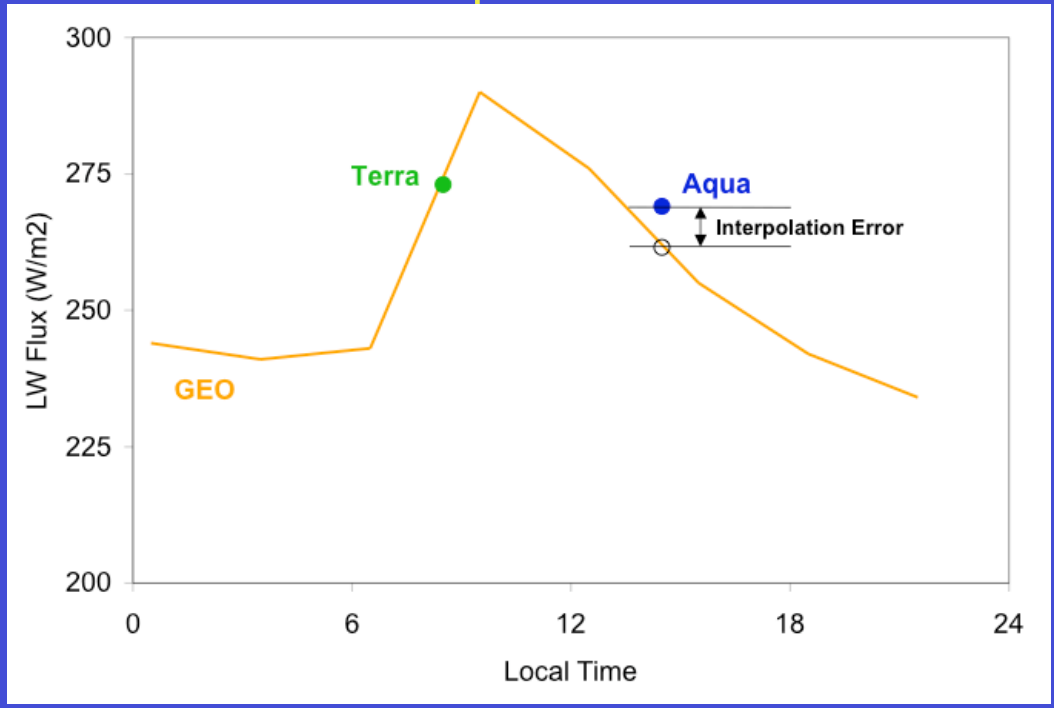
Wm-2	1986-1988	CERES Mar00 – Feb03		
All-Sky	ERBE	ERBE-like	nonGEO	GEO
OLR	236.3	239.0	237.7	237.1
SW	101.1	98.5	96.7	97.9
NET	4.9	3.8	6.9	6.4

SRBAVG Validation

- Aqua Terra Comparisons
  - Tests the instantaneous interpolation accuracy
- GEO calibration sensitivity study (VIS ±5%, IR ±5%)
  - Test effectiveness of GEO-CERES normalization
- 1 vs 3 hourly GEO derived fluxes
  - Tests for temporal sampling sensitivity
- Comparison of GEO surface fluxes with Surface flux measurements
  - Surface network provides an independent high temporal resolution data set
- Comparison of GEO BB fluxes with SARB
  - Consistency between cloud properties and fluxes
- Principal component (EOF) analysis of flux fields
  - Test for potential GEO viewing artifacts
- GEO derived directional models
  - Tests the NB-BB consistency with SZA

Aqua-Terra Comparisons

- Use the flux observations from one satellite as an independent data set to test fluxes interpolated from the other



- The flux difference represents the total interpolation error from the NB-BB, calibration, ADMs, and normalization
- Aqua/Terra monthly mean flux consistency also tested

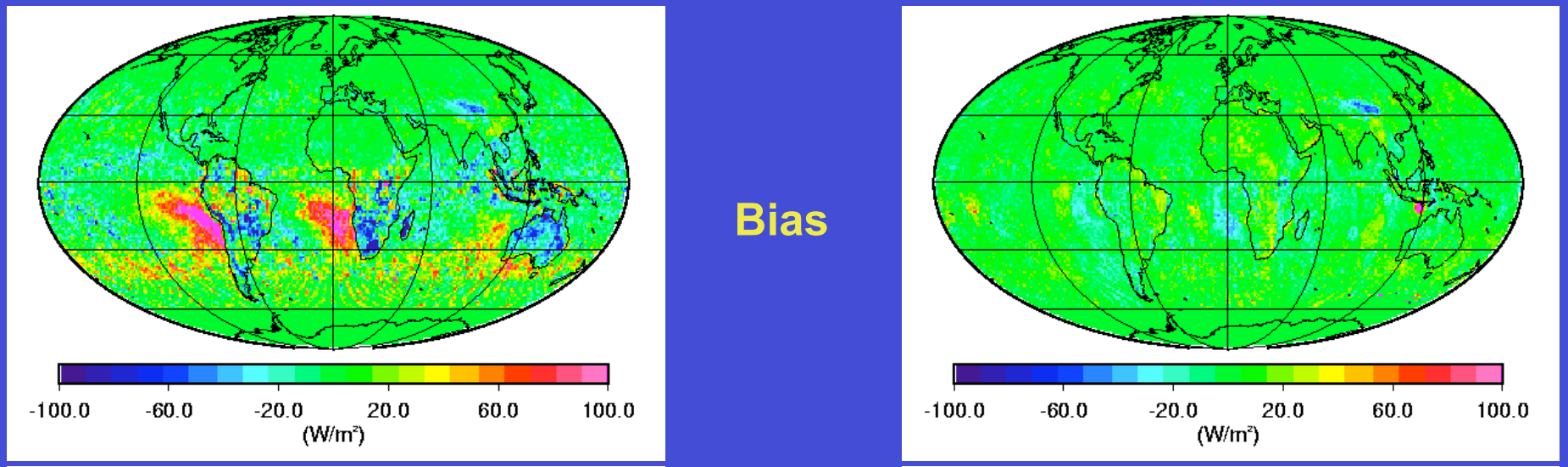
Terra Interpolated vs. Aqua Observed Total-sky TOA SW Flux

Instantaneous December 2002

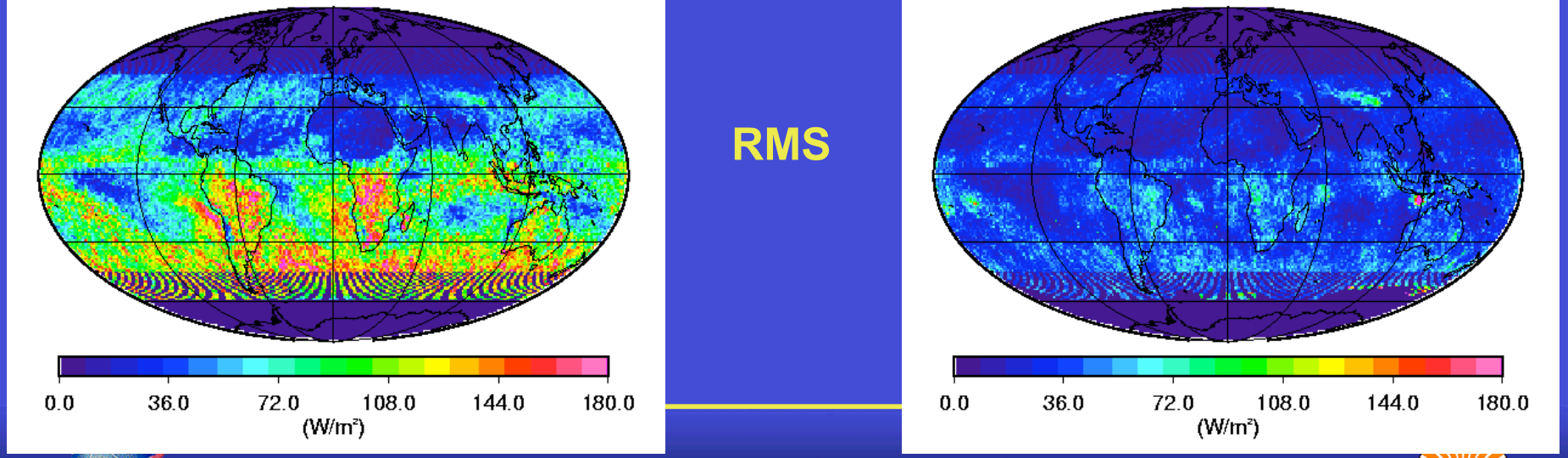
nonGEO

GEO

Bias



RMS



Instantaneous Total-sky TOA SW Flux Interpolation Differences

60°N to 60°S July 2002 - February 2003

Bias

SWtot BIAS	nonGEO		GEOtot	
Wm-2	Terra	Aqua	Terra	Aqua
OCN	5.0	-6.1	-0.2	0.9
(%)	2.2	-2.6	-0.1	0.4
LND	-9.6	9.2	3.0	2.6
(%)	-3.3	3.3	1.0	0.9
DES	-6.8	6.3	4.7	5.0
(%)	-2.4	2.3	1.7	1.8
ALL	1.5	-2.4	0.6	1.7
(%)	0.6	-1.0	0.3	0.7

RMS

SWtot RMS	nonGEO		GEO	
Wm-2	Terra	Aqua	Terra	Aqua
OCN	84.0	84.4	34.6	38.3
(%)	36.9	36.2	15.3	16.6
LND	87.4	88.3	37.9	36.4
(%)	30.1	31.2	13.0	12.8
DES	51.4	51.2	27.3	25.9
(%)	18.4	18.6	9.8	9.4
ALL	81.4	81.8	35.0	37.3
(%)	33.7	33.5	14.5	15.4

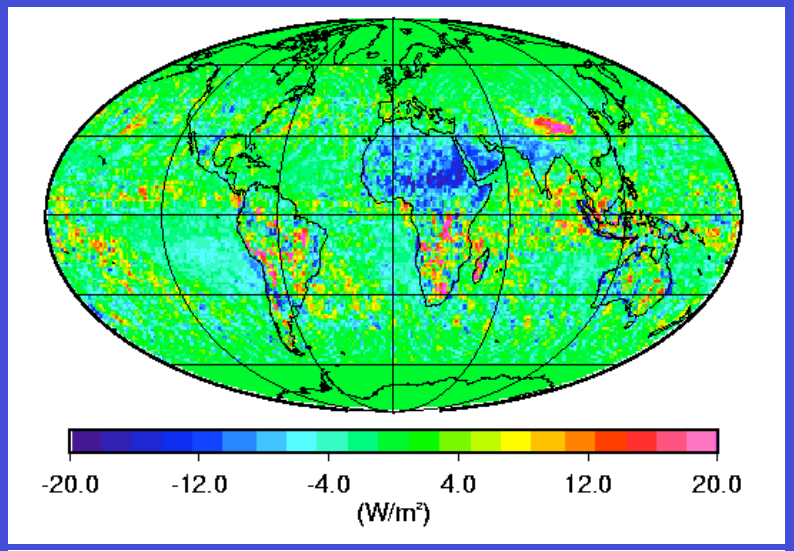
Terra Interpolated vs. Aqua Observed Total-sky TOA LW Flux

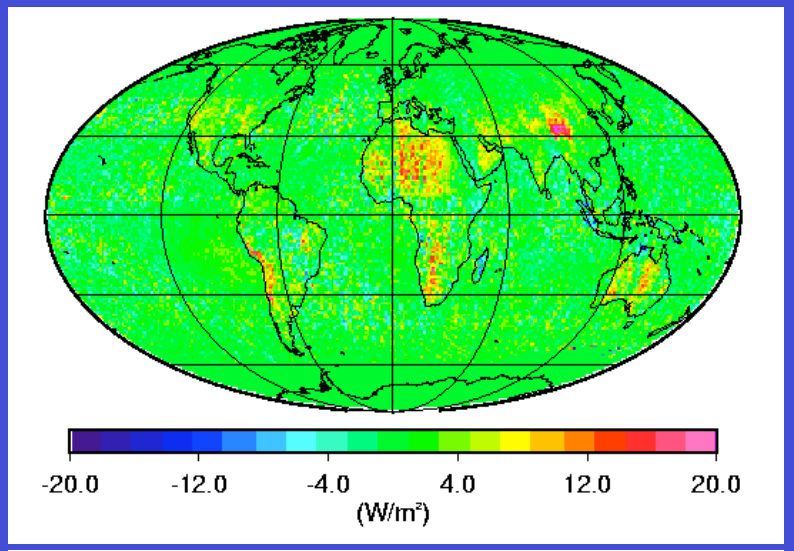
Daytime December 2002

nonGEO

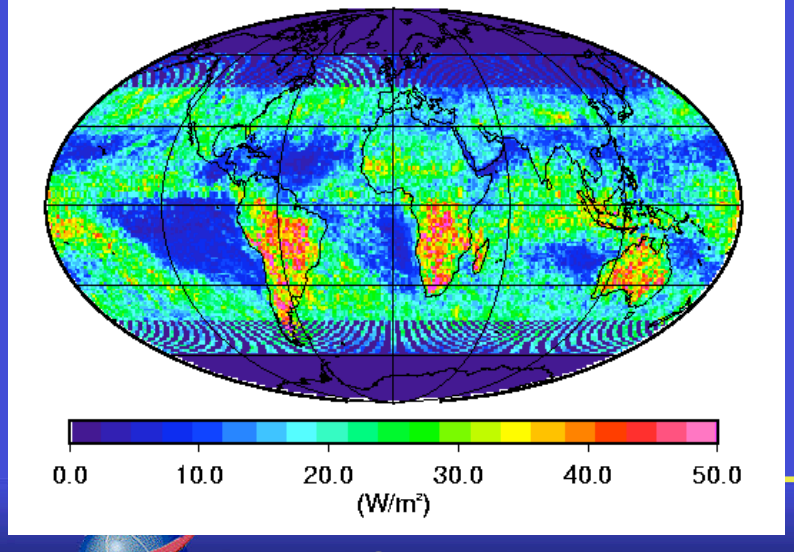
GEO

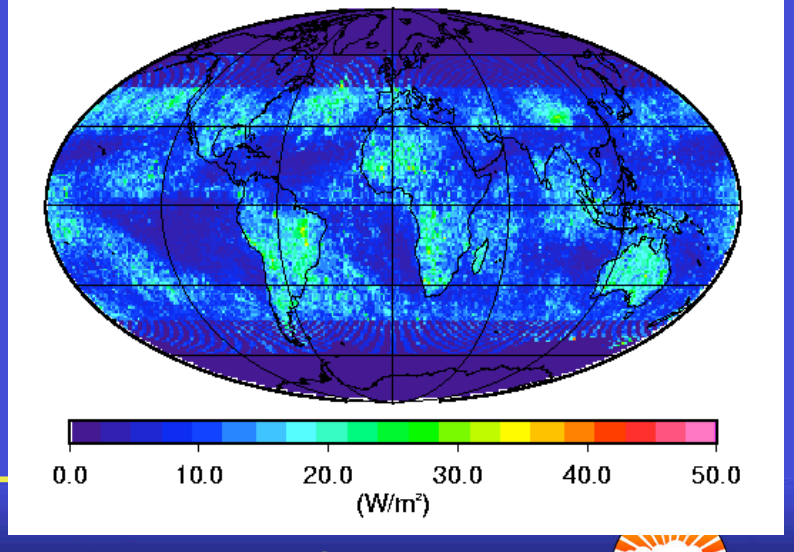
Bias





RMS





Instantaneous Total-sky TOA LW Flux Interpolation Differences

DAY July 2002 - February 2003

Bias

LWday BIAS	nonGEO		GEO	
Wm-2	Terra	Aqua	Terra	Aqua
OCN	-0.8	1.1	-0.1	1.7
(%)	-0.3	0.4	0.0	0.7
LND	-1.3	-0.1	2.1	1.9
(%)	-0.5	-0.1	0.8	0.8
DES	-6.0	3.5	4.3	2.5
(%)	-2.1	1.2	1.5	0.9
ALL	-1.1	0.9	0.6	1.8
(%)	-0.5	0.4	0.2	0.7

RMS

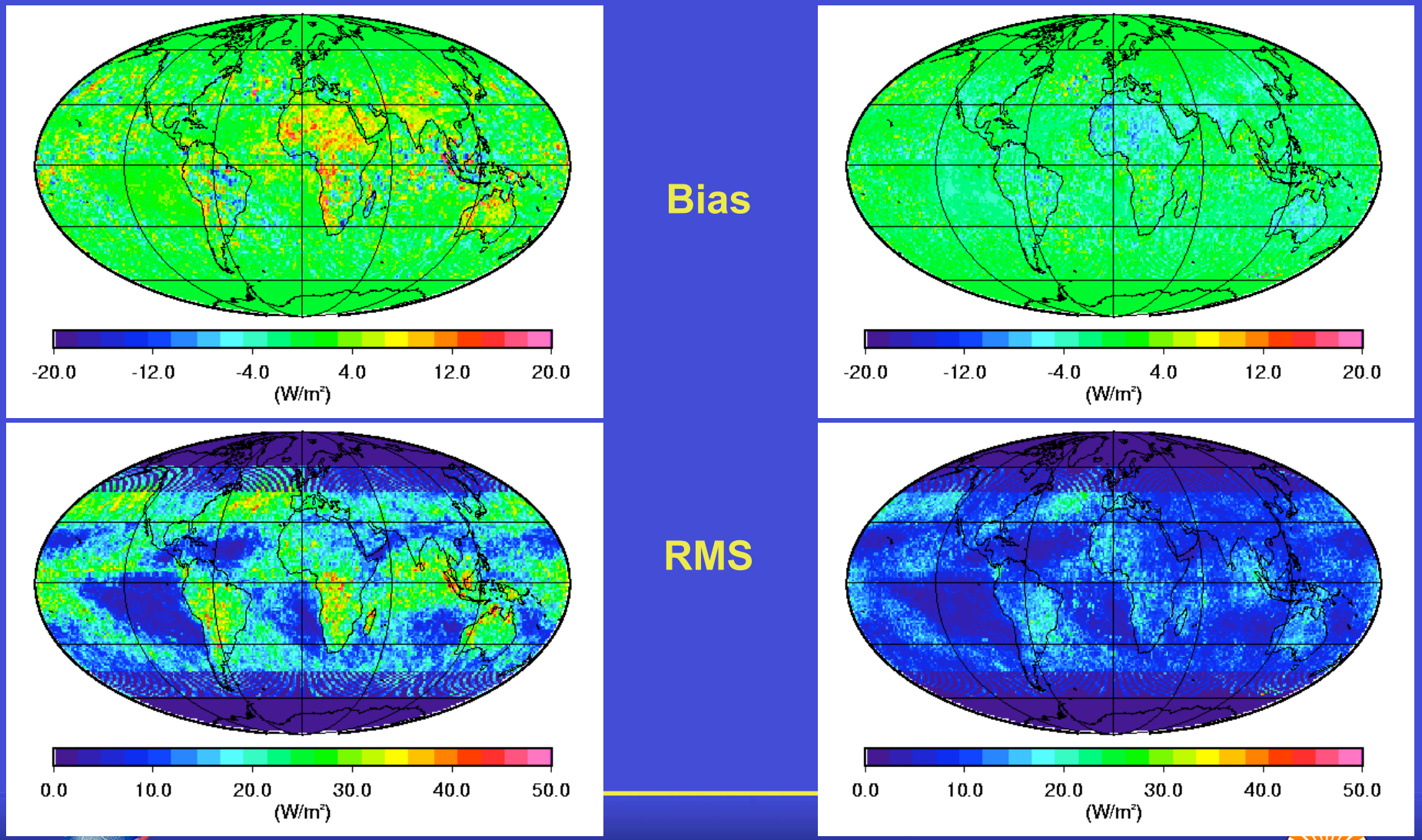
LWday RMS	nonGEO		GEO	
Wm-2	Terra	Aqua	Terra	Aqua
OCN	18.7	19.4	10.7	10.8
(%)	7.5	7.9	4.3	4.4
LND	25.7	25.3	13.9	13.6
(%)	10.1	9.9	5.4	5.3
DES	22.5	22.5	13.9	13.1
(%)	7.7	7.8	4.8	4.6
ALL	20.1	20.5	11.4	11.4
(%)	8.0	8.2	4.6	4.6

Terra Interpolated vs. Aqua Observed Total-sky TOA LW Flux

Nighttime December 2002

nonGEO

GEO



Instantaneous Total-sky TOA LW Flux Interpolation Differences

NIGHT July 2002 - February 2003

Bias

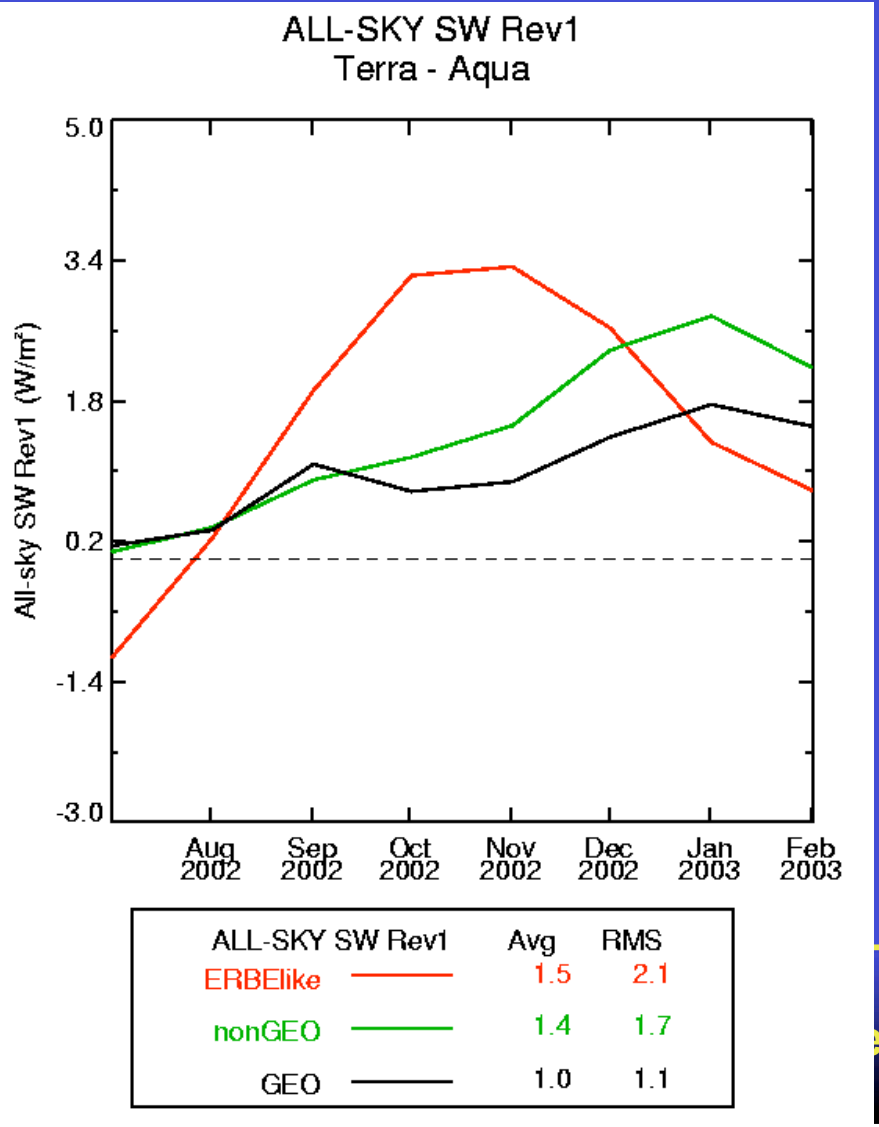
LWnit BIAS	nonGEO		GEOtot	
Wm-2	Terra	Aqua	Terra	Aqua
OCN	0.4	-0.6	-0.8	-0.6
(%)	0.2	-0.2	-0.3	-0.2
LND	1.4	1.1	-2.4	-1.1
(%)	0.6	0.5	-1.0	-0.5
DES	3.9	2.0	-4.1	-2.4
(%)	1.5	0.8	-1.6	-0.9
ALL	0.8	-0.1	-1.3	-0.8
(%)	0.3	0.0	-0.5	-0.3

RMS

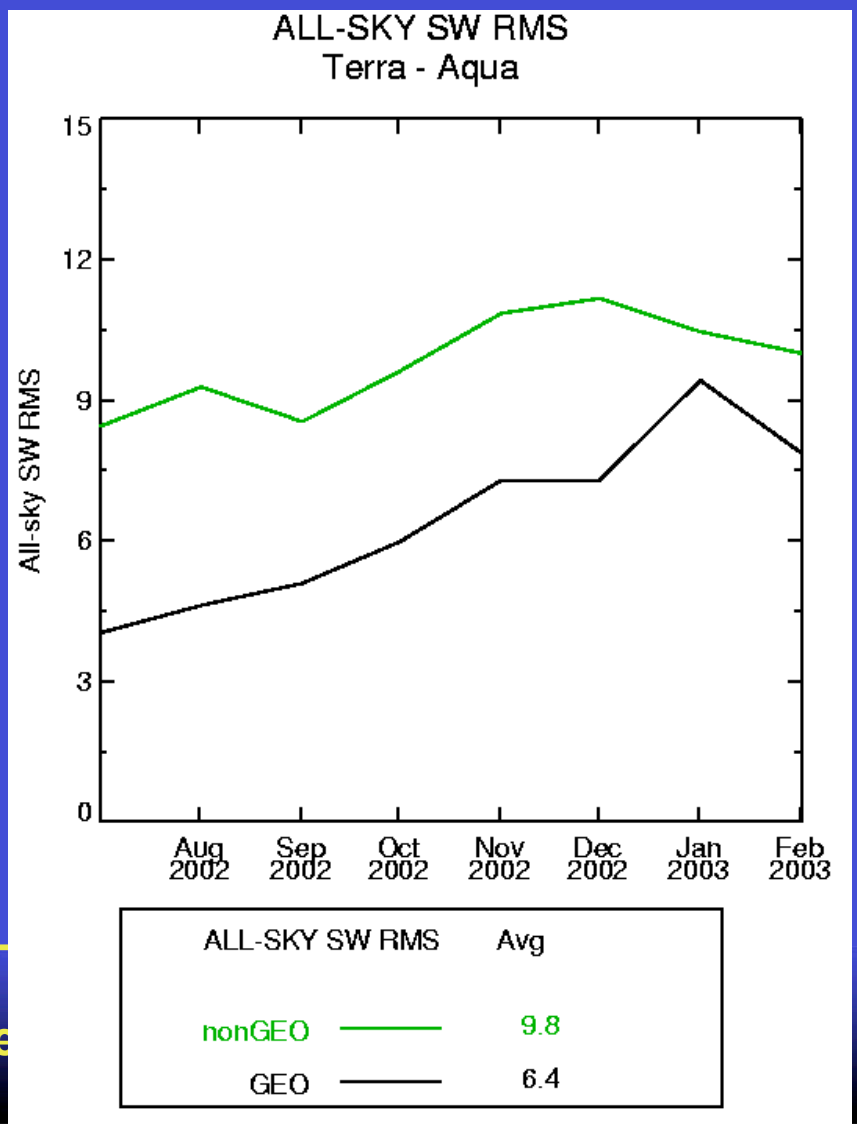
LWnit RMS	nonGEO		GEOtot	
Wm-2	Terra	Aqua	Terra	Aqua
OCN	17.5	18.9	10.4	11.0
(%)	7.0	7.6	4.2	4.4
LND	22.6	25.9	12.0	13.5
(%)	9.6	10.9	5.1	5.7
DES	18.2	21.8	10.6	11.2
(%)	7.1	8.4	4.2	4.3
ALL	18.4	20.3	10.6	11.4
(%)	7.5	8.3	4.3	4.7

SW Terra-Aqua Monthly Mean Comparisons

Global BIAS

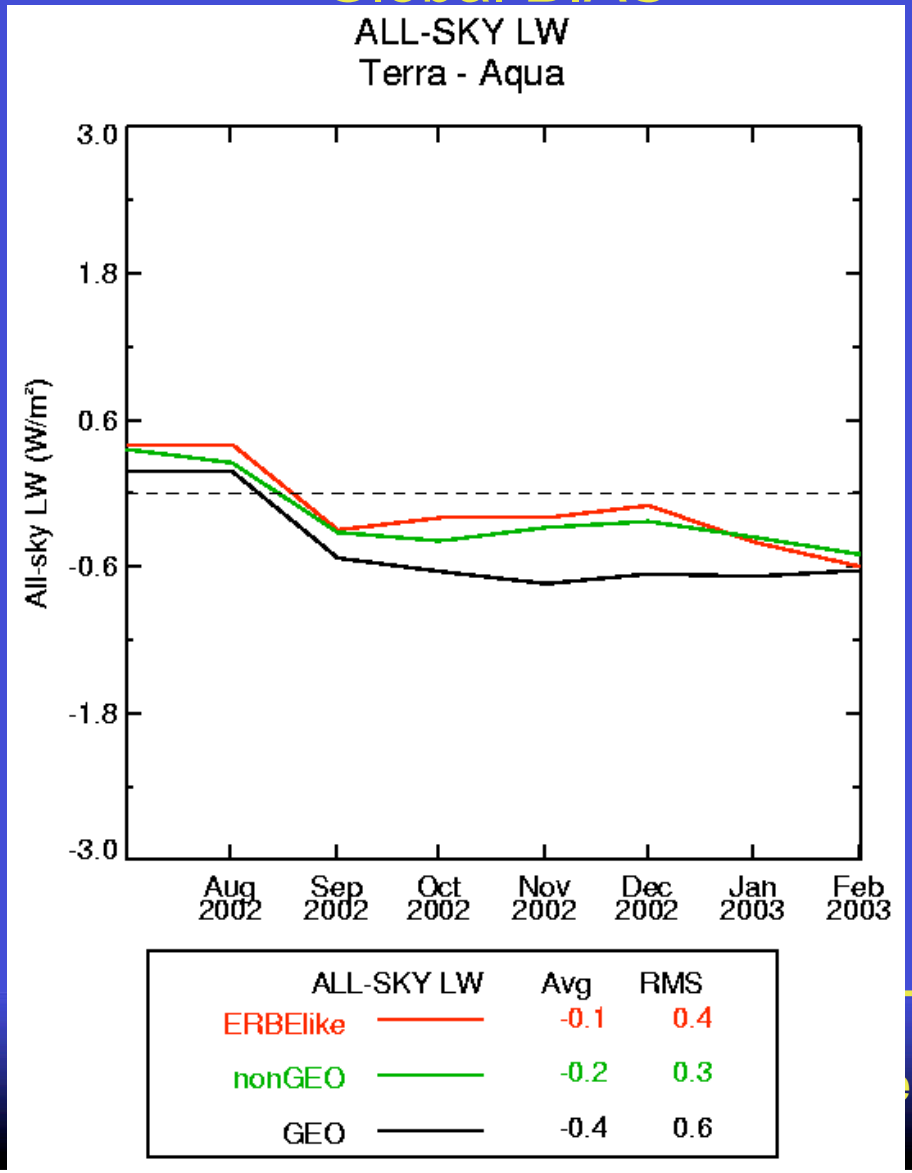


Regional 60°N to 60°S RMS

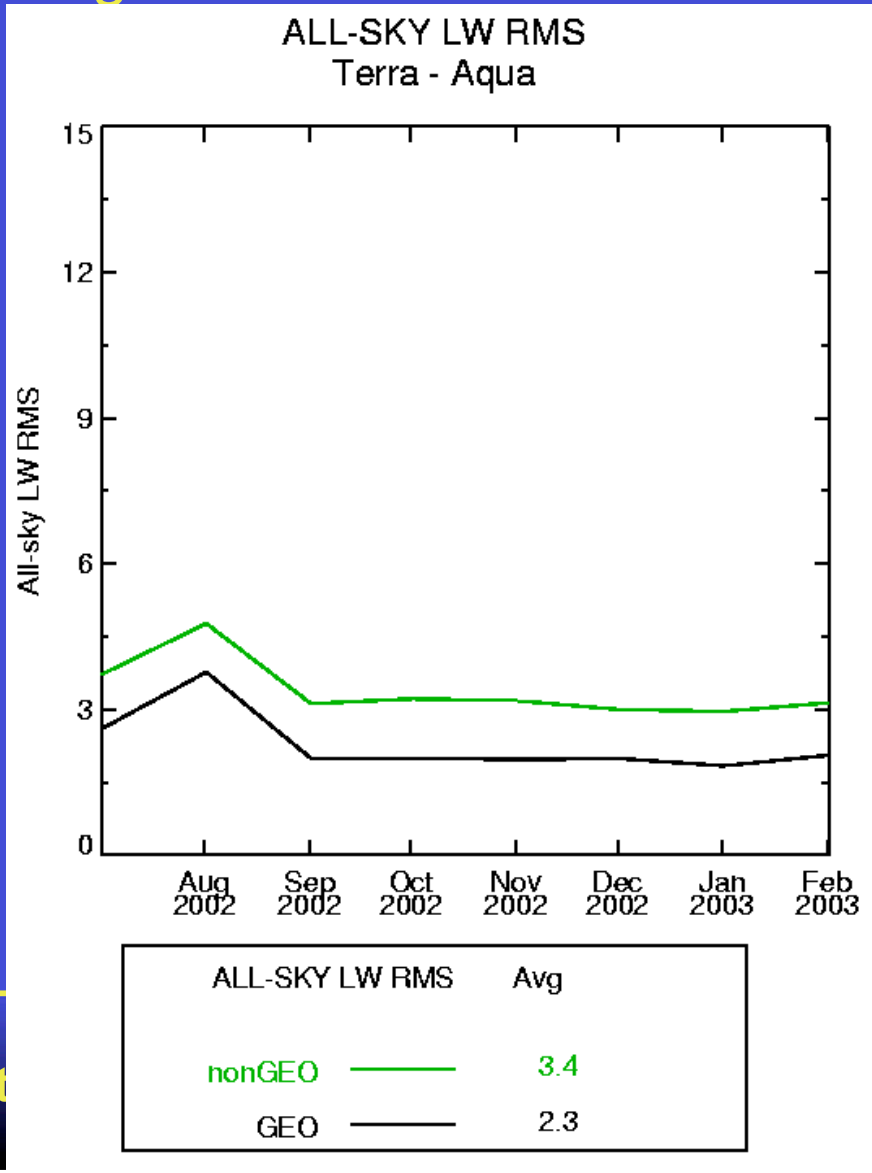


LW Terra-Aqua Monthly Mean Comparisons

Global BIAS



Regional 60°N to 60°S RMS



Aqua-Terra Comparison Summary

- Global mean instantaneous GEO differences are within 1%
  - Possible night time negative bias over deserts for LW night
- Instantaneous GEO rms differences are 15% and 4.5% for SW and LW respectively
  - A 50% reduction from non-GEO for both SW and LW

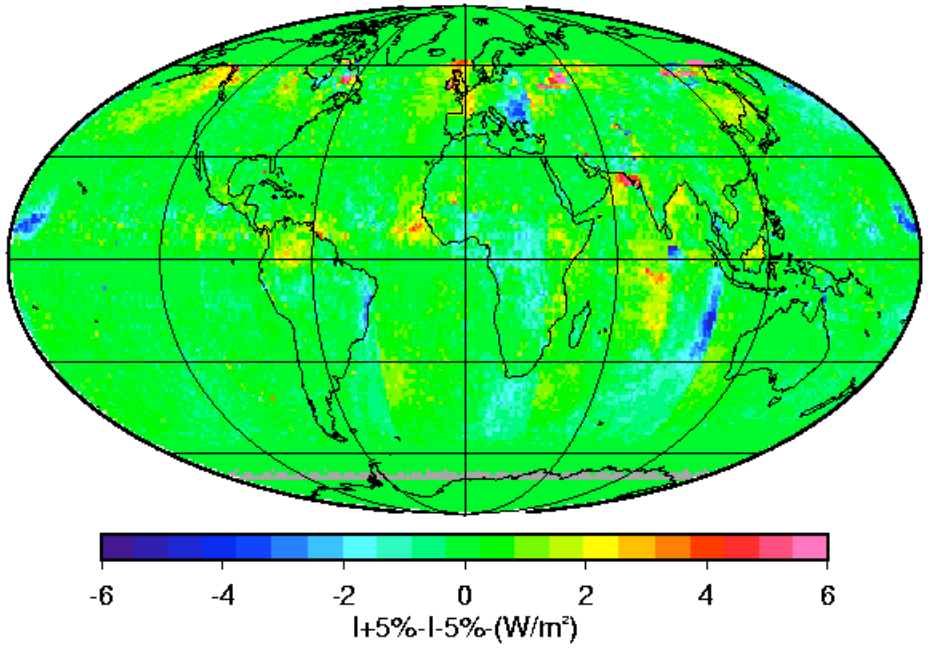
- Monthly mean global SW GEO differences (1%) are less than either nonGEO or ERBE-like
  - The LW GEO land night may have issues, (bias -0.2%)
- Monthly mean regional GEO RMS differences are 6.5% and 1.0% for SW and LW respectively
  - A ~30% reduction from non-GEO

GEO calibration sensitivity study

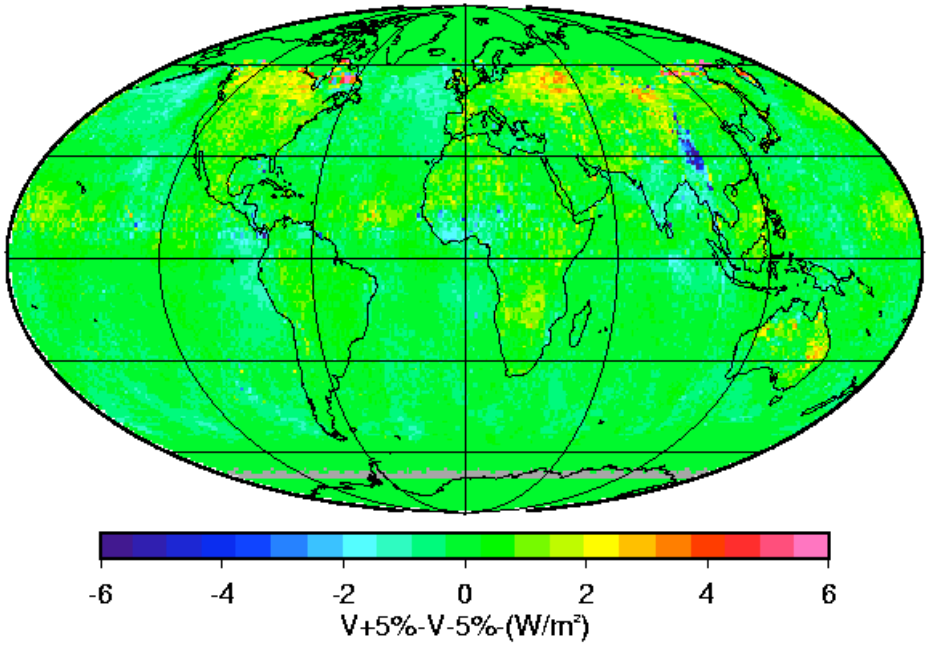
- Purpose
  - Test the effectiveness of the GEO-CERES normalization
- GEO imager data
  - Poorly calibrated
  - GEO radiances are calibrated against MODIS
  - Calibration accuracy VIS 3-5% and ~1% IR
- Method
  - Modify the GEO radiances by ±5%
  - Reprocess GEO cloud analysis and rerun interpolation
  - Compare monthly mean fluxes to assess impact
- Earlier TRMM study found <0.1% LW change and 1% SW

Change in Total-Sky TOA SW Flux, July 2002

(IR+5%) - (IR-5%)



(VIS+5%) - (VIS-5%)

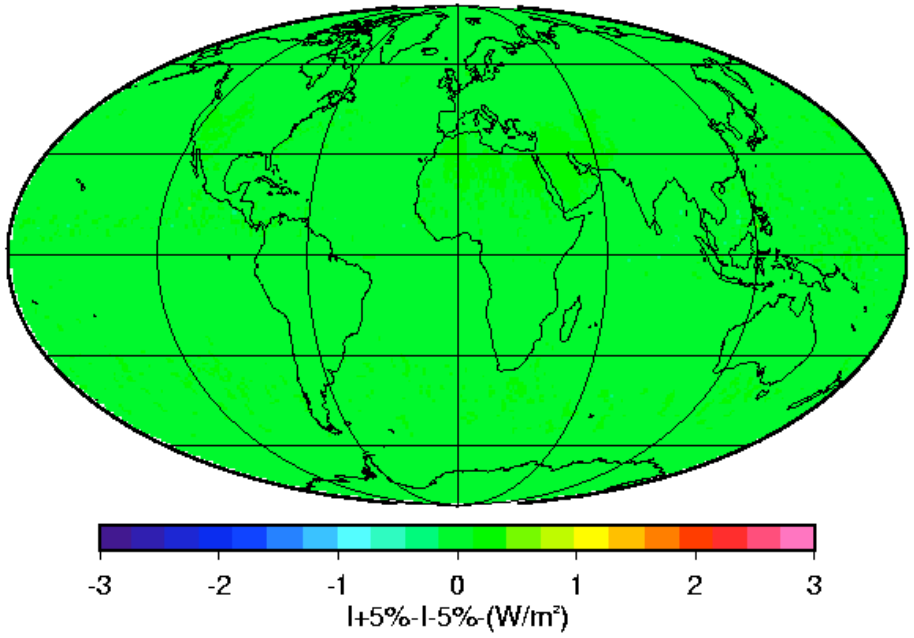


	I+5%	I-5%	I+5%-I-5%	reg RMS
Global	91.51	91.41	0.10	0.81

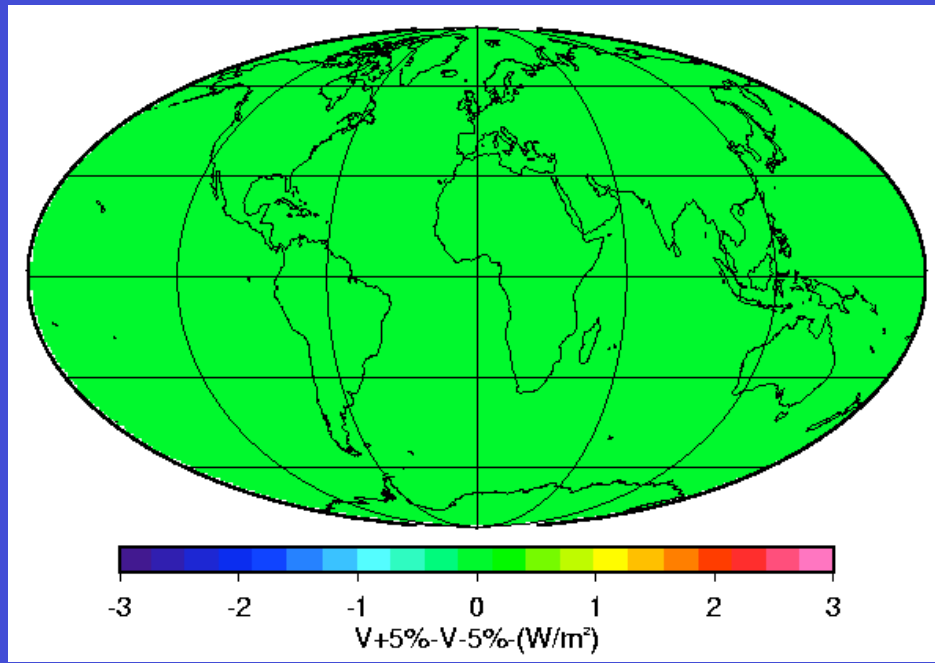
	V+5%	V-5%	V+5%-V-5%	reg RMS
Global	91.49	91.48	0.01	0.70

Change in Total-Sky TOA LW Flux, July 2002

(IR+5%) - (IR-5%)



(VIS+5%) - (VIS-5%)

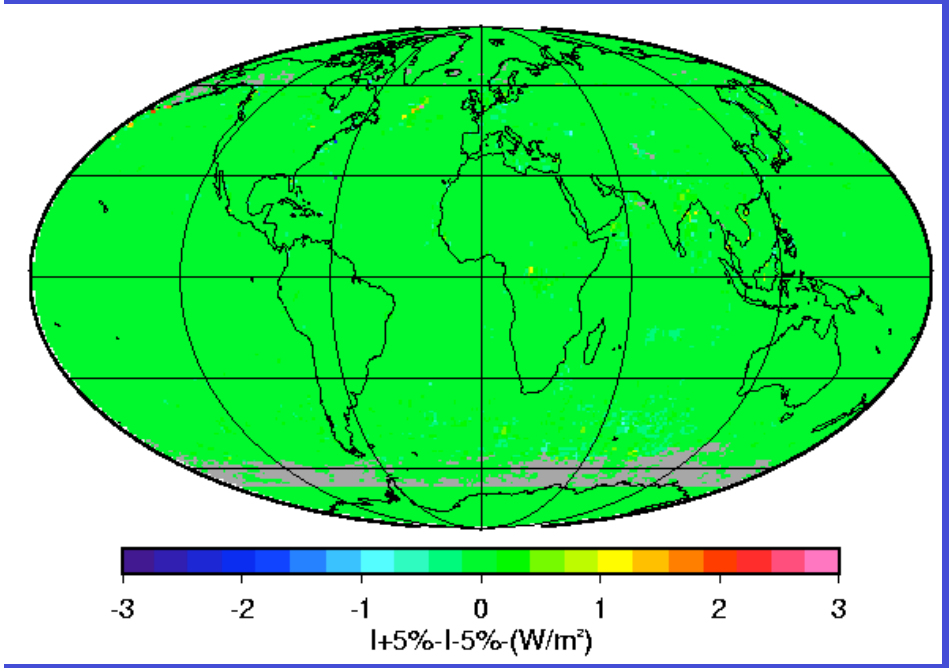


	I+5%	I-5%	I+5%-I-5%	reg RMS
Global	242.00	241.98	0.02	0.06

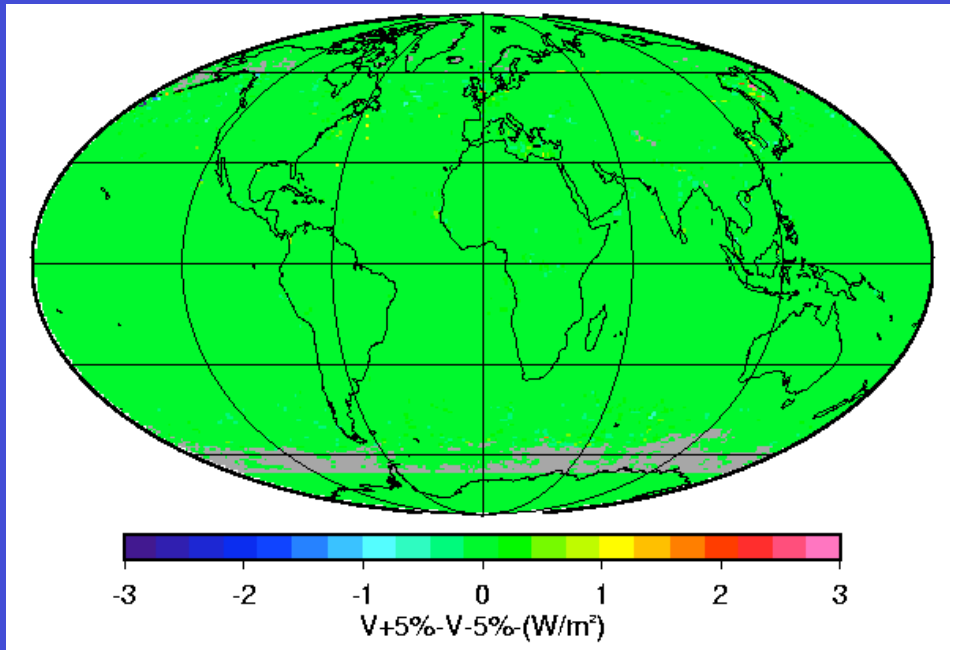
	V+5%	V-5%	V+5%-V-5%	reg RMS
Global	241.99	241.99	0.00	0.00

Change in Clear-Sky TOA SW Flux, July 2002

(IR+5%) - (IR-5%)



(VIS+5%) - (VIS-5%)

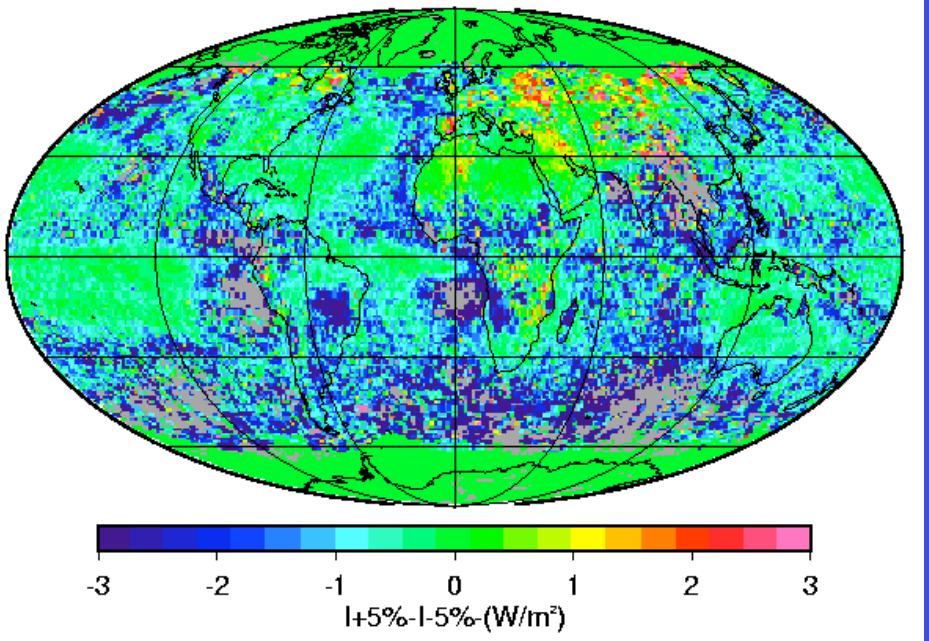


	I+5%	I-5%	I+5%-I-5%	reg RMS
Global	46.23	46.24	-0.00	0.10

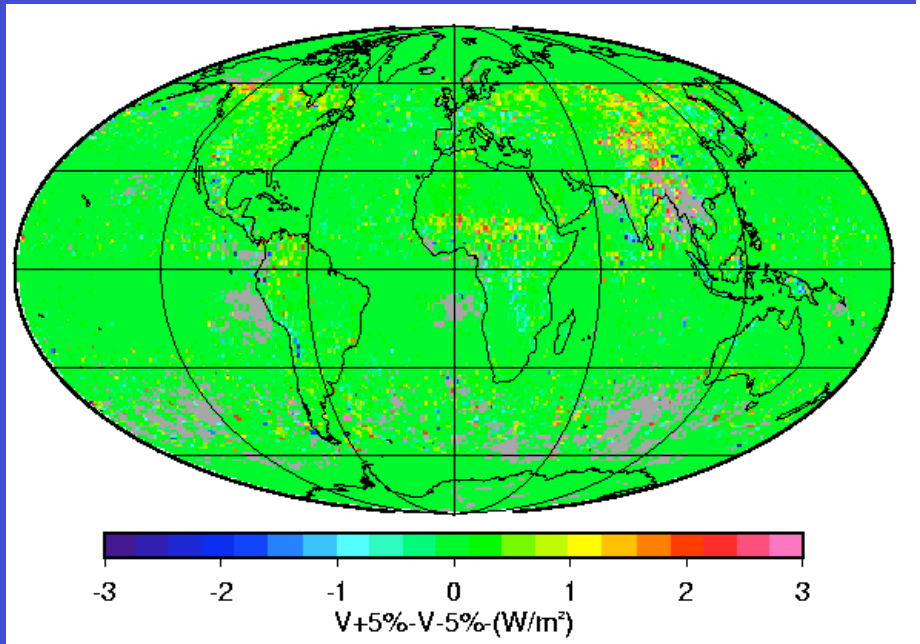
	V+5%	V-5%	V+5%-V-5%	reg RMS
Global	46.23	46.23	0.00	0.12

Change in Clear-Sky TOA LW Flux, July 2002

(IR+5%) - (IR-5%)



(VIS+5%) - (VIS-5%)



	I+5%	I-5%	I+5%-I-5%	reg RMS
Global	268.91	269.83	-0.93	1.85

	V+5%	V-5%	V+5%-V-5%	reg RMS
Global	269.32	269.24	0.08	0.47

Summary of GEO calibration sensitivity study

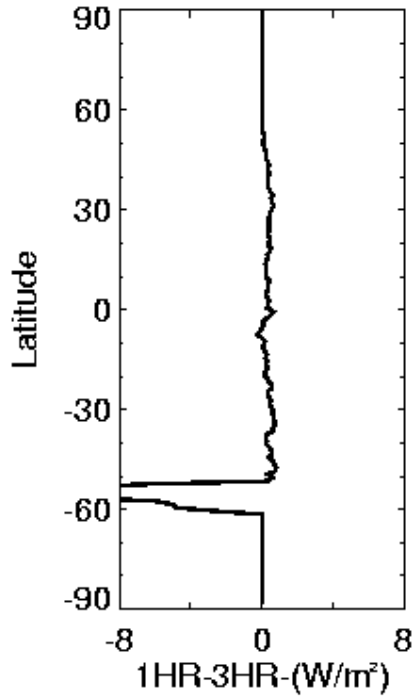
- Total-sky flux sensitivity is <0.1% (<1% rms)
  - Except for clear-sky LW in IR 0.35%
  - LW and clear-sky SW bias and RMS differences are negligible
  - Plotted differences are for 10% change in calibration
    - SW calibration uncertainty is within 3-5%
    - LW calibration uncertainty is within 1-2%
- Regional differences can exceed 2% in limited areas
  - SW normalization time match differences (longitudonal striping)
  - Northern Latitudes
  - Slight bias (1-2%) in deep convection
- Clear-sky fluxes show effect from changes in scene ID
  - IR+5% had the only statistically significant bias
- For global mean flux, the GEO-CERES normalization removes sensitivity to GEO calibration

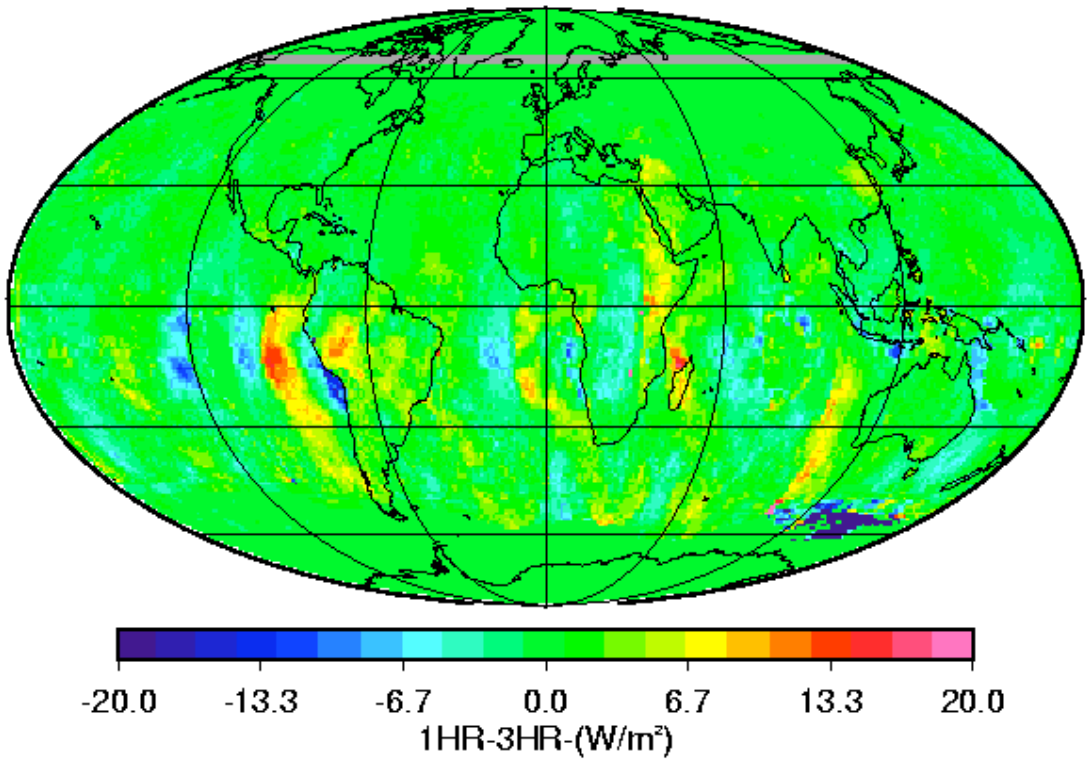
GEO Sampling Sensitivity

- Purpose
  - Evaluate the error due to using 3-hourly sampled GEO data
- Method
  - Compare monthly mean fluxes produced using 1-hourly and 3-hourly resolution GEO data

Change in Total-Sky TOA SW Flux 1-hrly - 3-hrly

December 2002

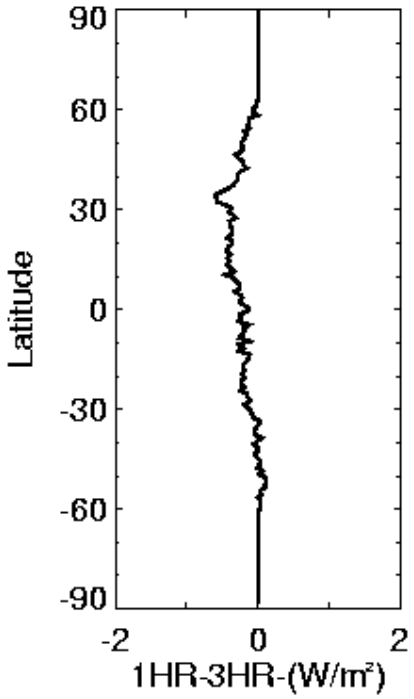


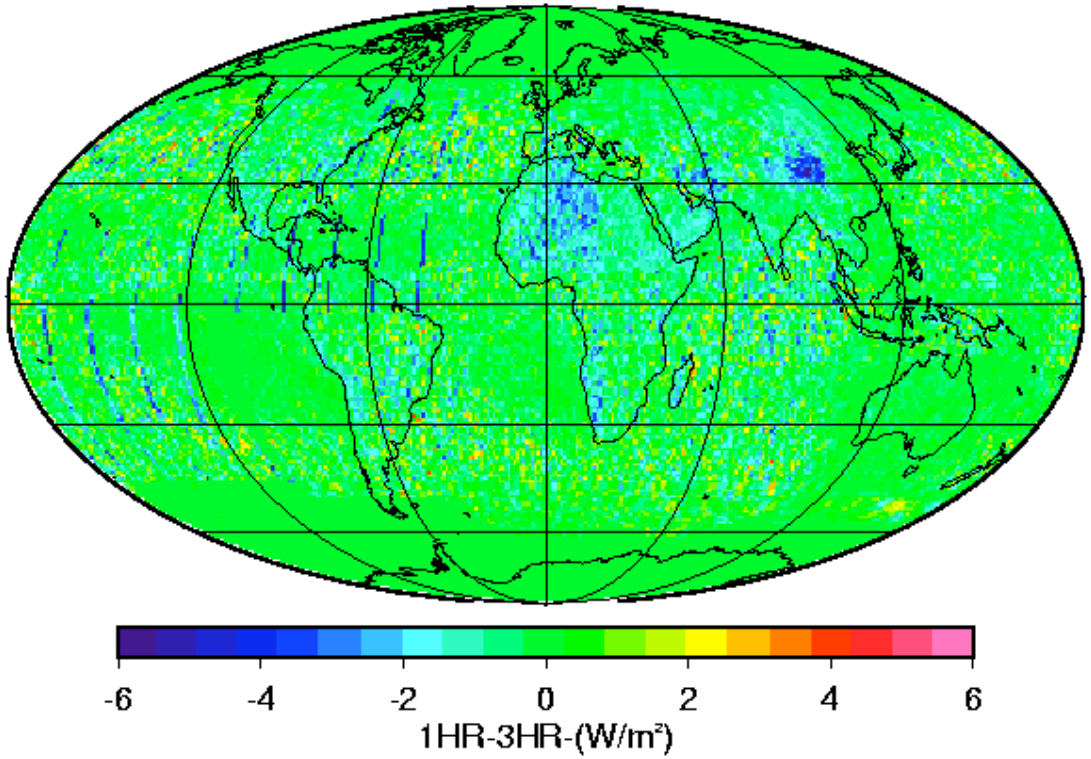


	1HR	3HR	1HR-3HR	reg RMS
Global	105.27	105.33	-0.06	2.61

Change in Total-Sky TOA LW Flux 1-3 hourly

December 2002





	1HR	3HR	1HR-3HR	reg RMS
Global	233.44	233.63	-0.19	0.97

Summary of 1-hourly vs 3-hourly study

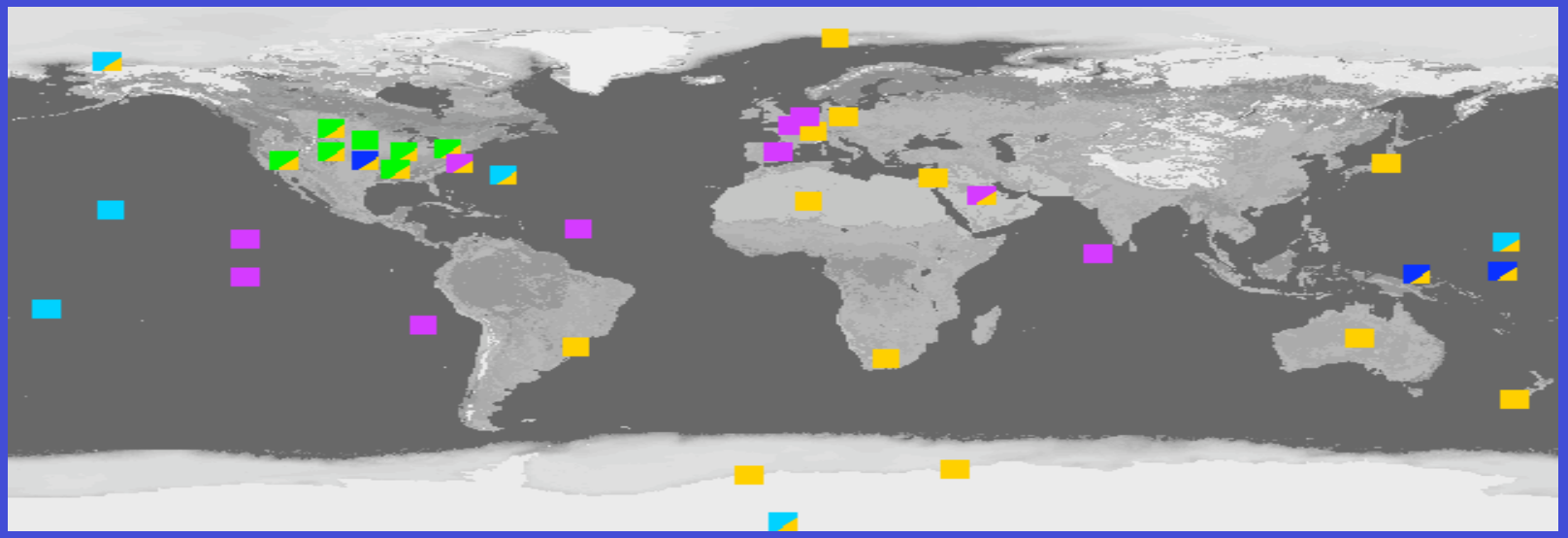
- Total-sky flux bias differences are <0.1%
- 2.5% SW and 0.4% LW RMS
- SW glint and variation of time matches in SW normalization

Surface Flux Comparison Purpose

- Test CERES-derived surface fluxes with the surface data network
- Surface flux data is one of the few independent high resolution datasets available

Surface Flux Comparisons

- Compare station surface LW and SW fluxes with SRBAVG monthly Model B (all-sky) LPSA/LPLA (Gupta model) fluxes



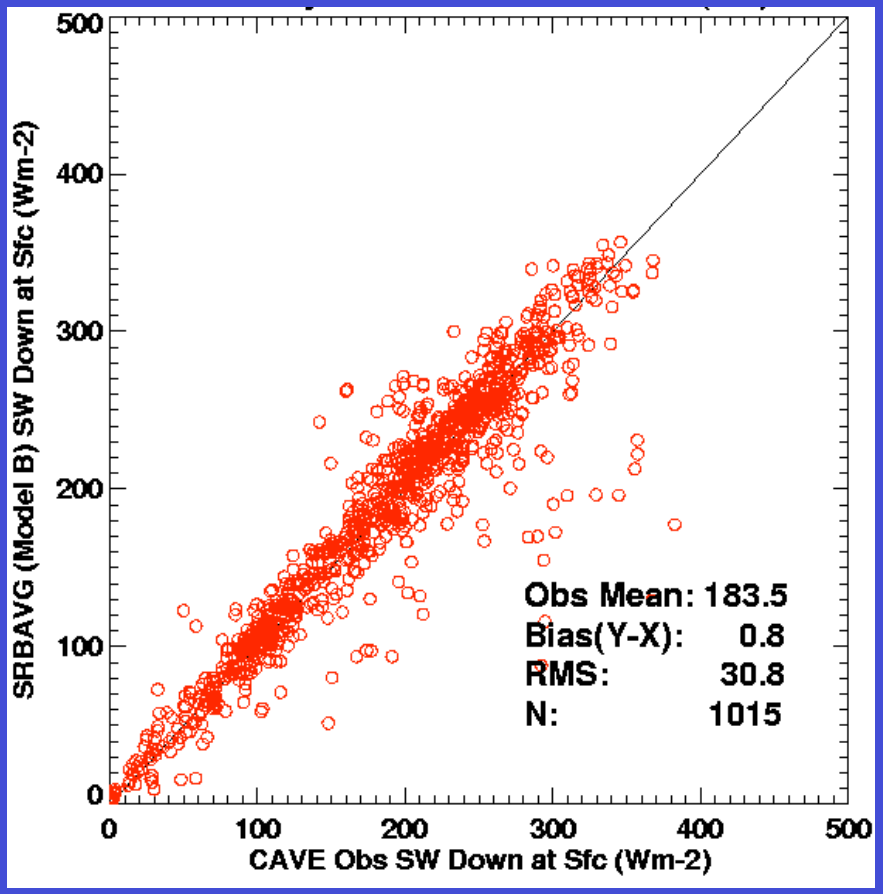
- Monthly site surface fluxes from CAVE
  - –ARM, SURFRAD, CMDL, and BSRN quality controlled surface radiometer networks
  - –3 years of monthly fluxes per station (Mar00 to Feb03)
  - –36 stations across the globe

Surface Flux Comparisons

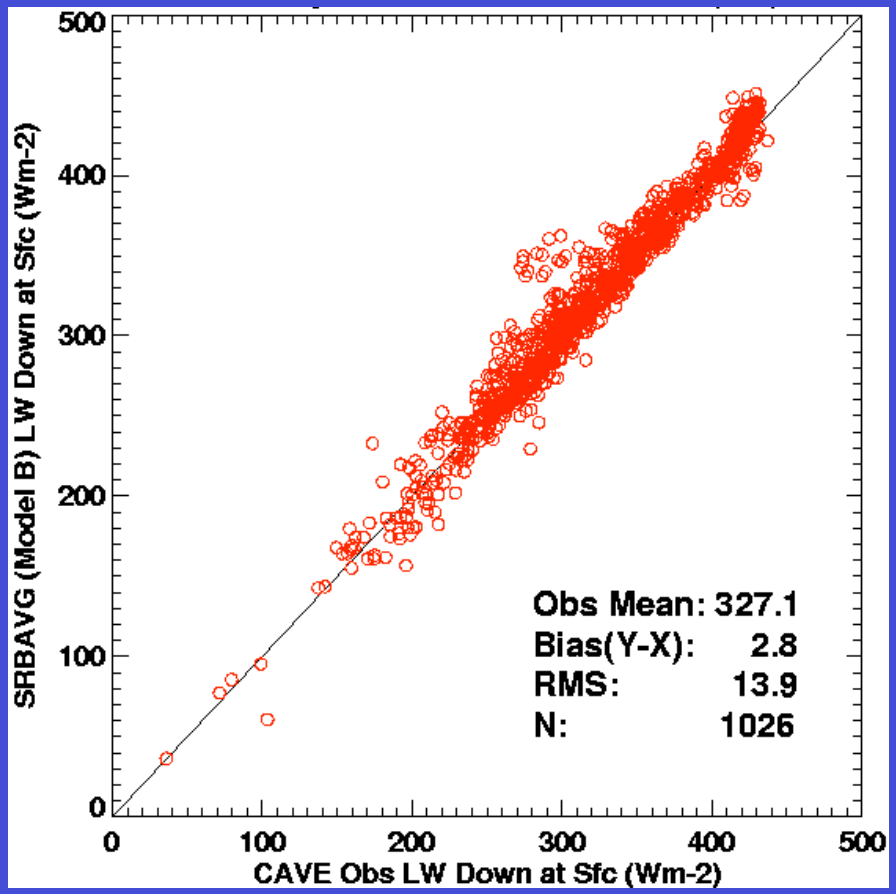
- LPLA Longwave fluxes
  - Surface longwave fluxes are independent from TOA
  - GEOS atmospheric state vertical profiles
  - GEO (low) cloud base heights
- LPSA shortwave fluxes
  - SW TOA major component
  - Cloud Amount
  - Cloud optical depth

Monthly Mean Surface Downwelling Flux Comparisons

SW



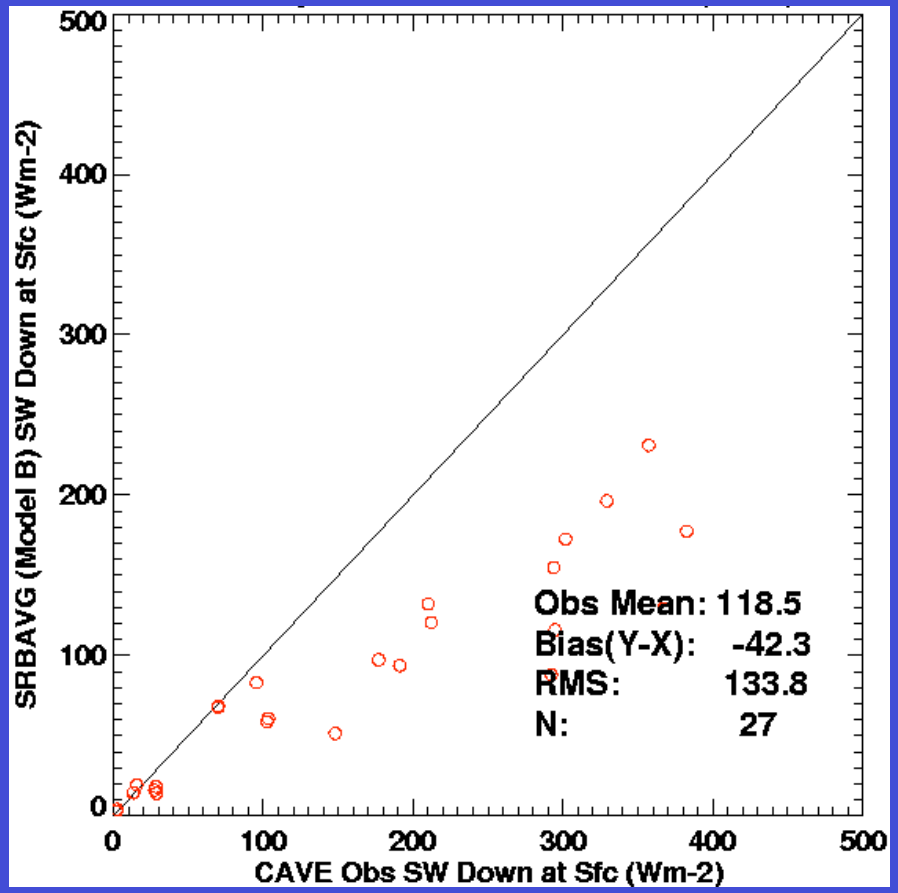
LW



Monthly Mean Surface Downwelling Flux Comparisons

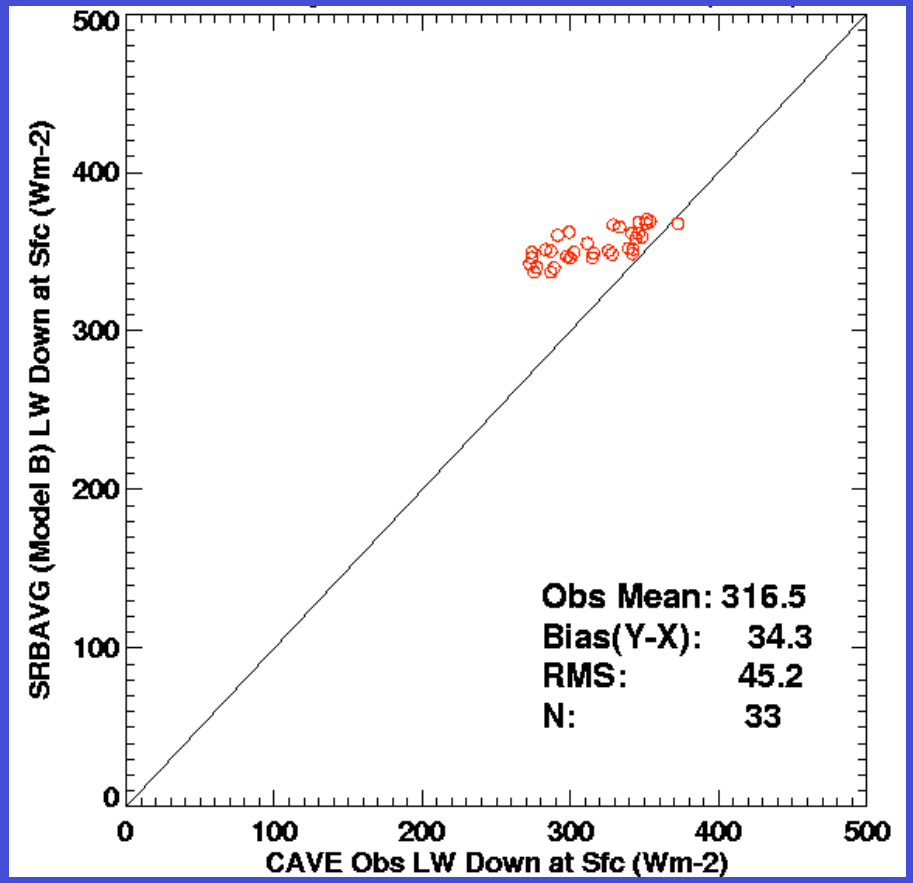
SW

Georg von Neumeyer, Antarctica



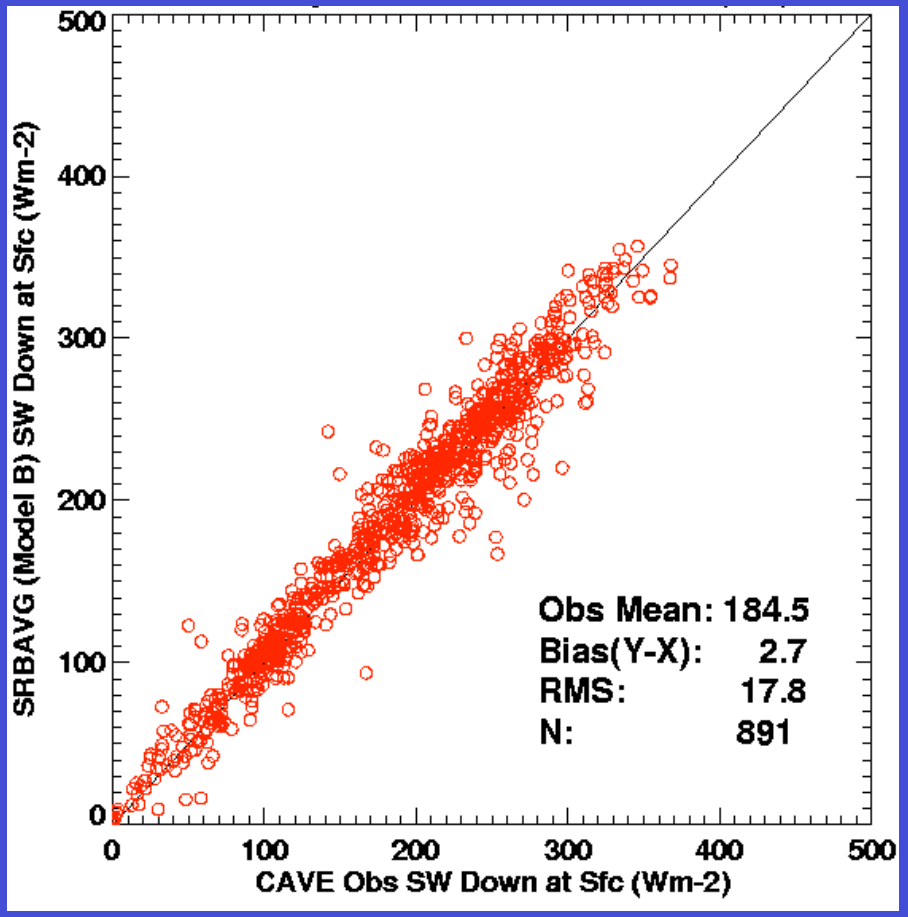
LW

De Aar, South Africa

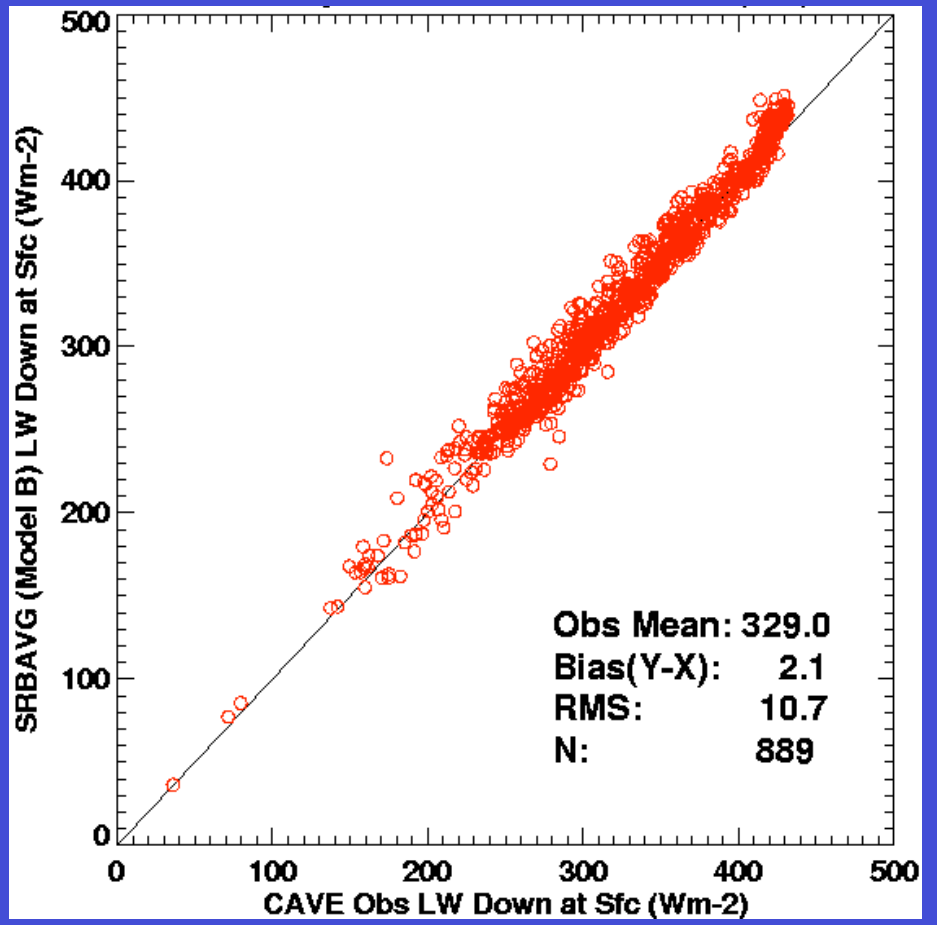


Monthly Mean Surface Downwelling Flux Comparisons (4 stations removed)

SW



LW



Summary of Surface Flux Comparison

- The monthly SRBAVG surface (Model B) regional and ground fluxes are within the bias and RMS errors derived from instantaneous CERES footprint Model B (SOFA) and ground fluxes
  - 32 station result
- Some surface stations (a point) may not representative of the 1° region, (coastal, terrain, etc.)

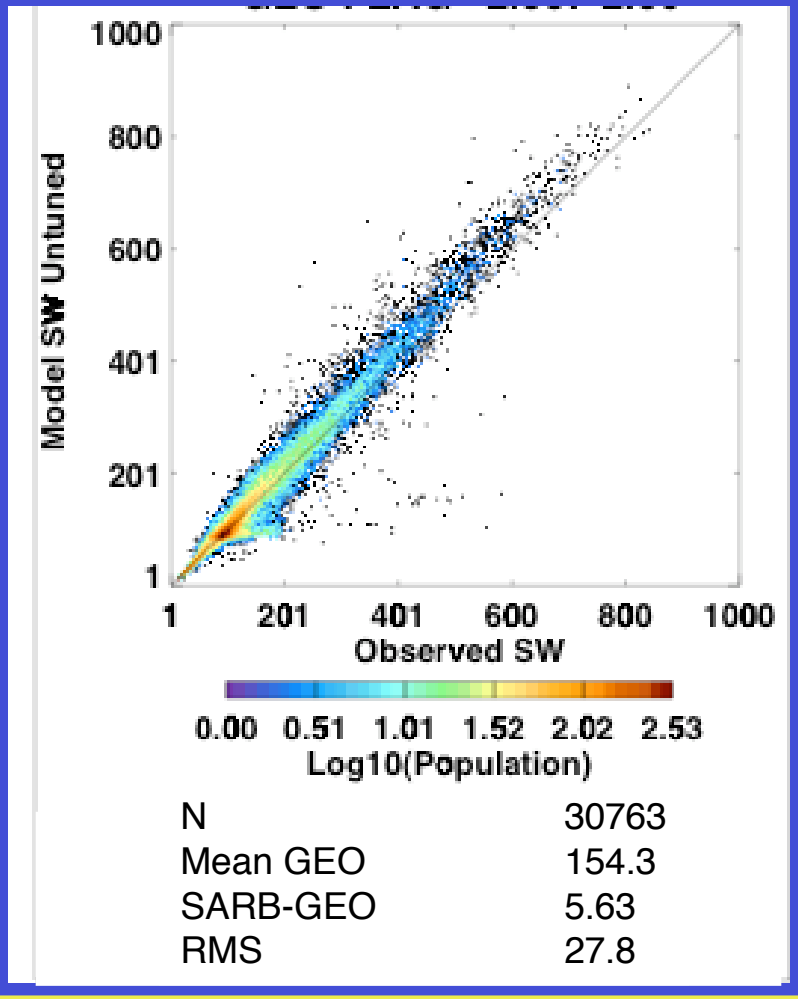
(%)	SW		LW	
	SOFA	SRBAVG	SOFA	SRBAVG
Bias	3.3	1.5	-0.6	0.6
RMS	15.0	9.6	7.4	3.3

Comparison of GEO BB fluxes with SARB

- Purpose
  - To check the consistency between the fluxes and the given cloud property and atmospheric inputs
  - SARB un-tuned flux estimates are from FU-Liou radiative transfer calculations based on input cloud property and GEOS profiles
- Method
  - Compute SYN for July 2002 for one latitude band
  - Compare with CERES fluxes and MODIS cloud properties as a baseline
  - Compare with GEO derived broadband fluxes and GEO cloud properties
    - Errors due to both NB to BB and cloud property errors
- Preliminary - first attempt results

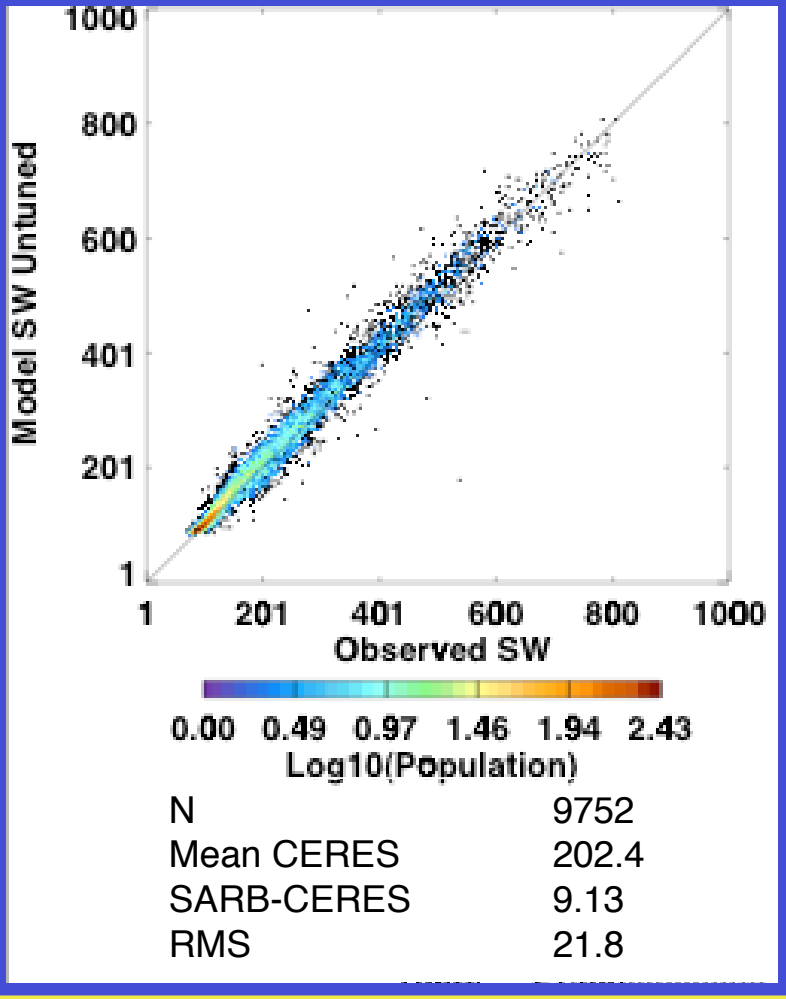
Comparison of GEO SW BB and CERES fluxes with SARB

GEO



N	30763
Mean GEO	154.3
SARB-GEO	5.63
RMS	27.8

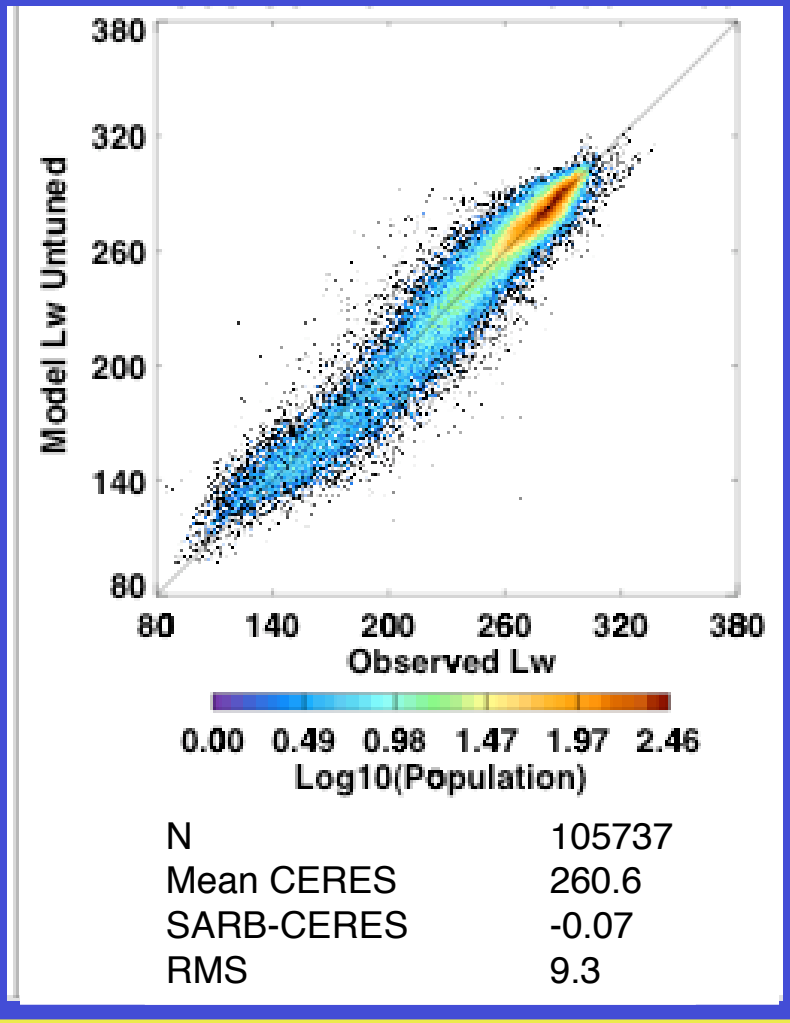
CERES



N	9752
Mean CERES	202.4
SARB-CERES	9.13
RMS	21.8

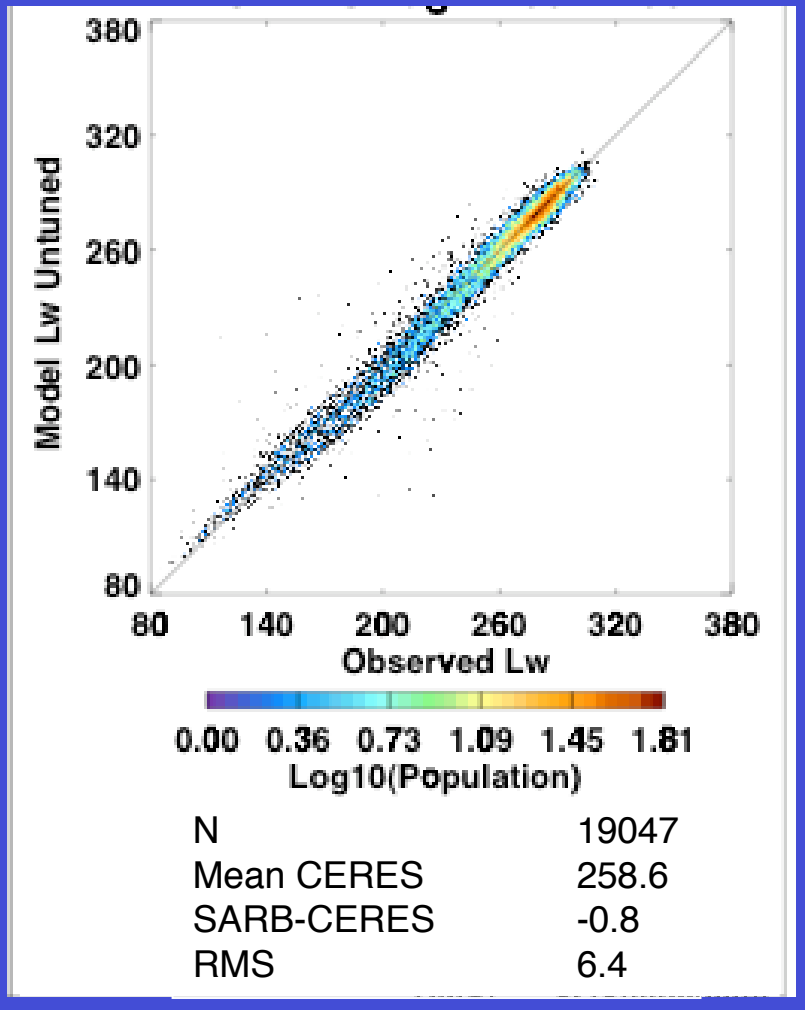
Comparison of GEO LW BB and CERES fluxes with SARB

GEO-daytime



N	105737
Mean CERES	260.6
SARB-CERES	-0.07
RMS	9.3

CERES



N	19047
Mean CERES	258.6
SARB-CERES	-0.8
RMS	6.4

Comparison of GEO BB fluxes with SARB

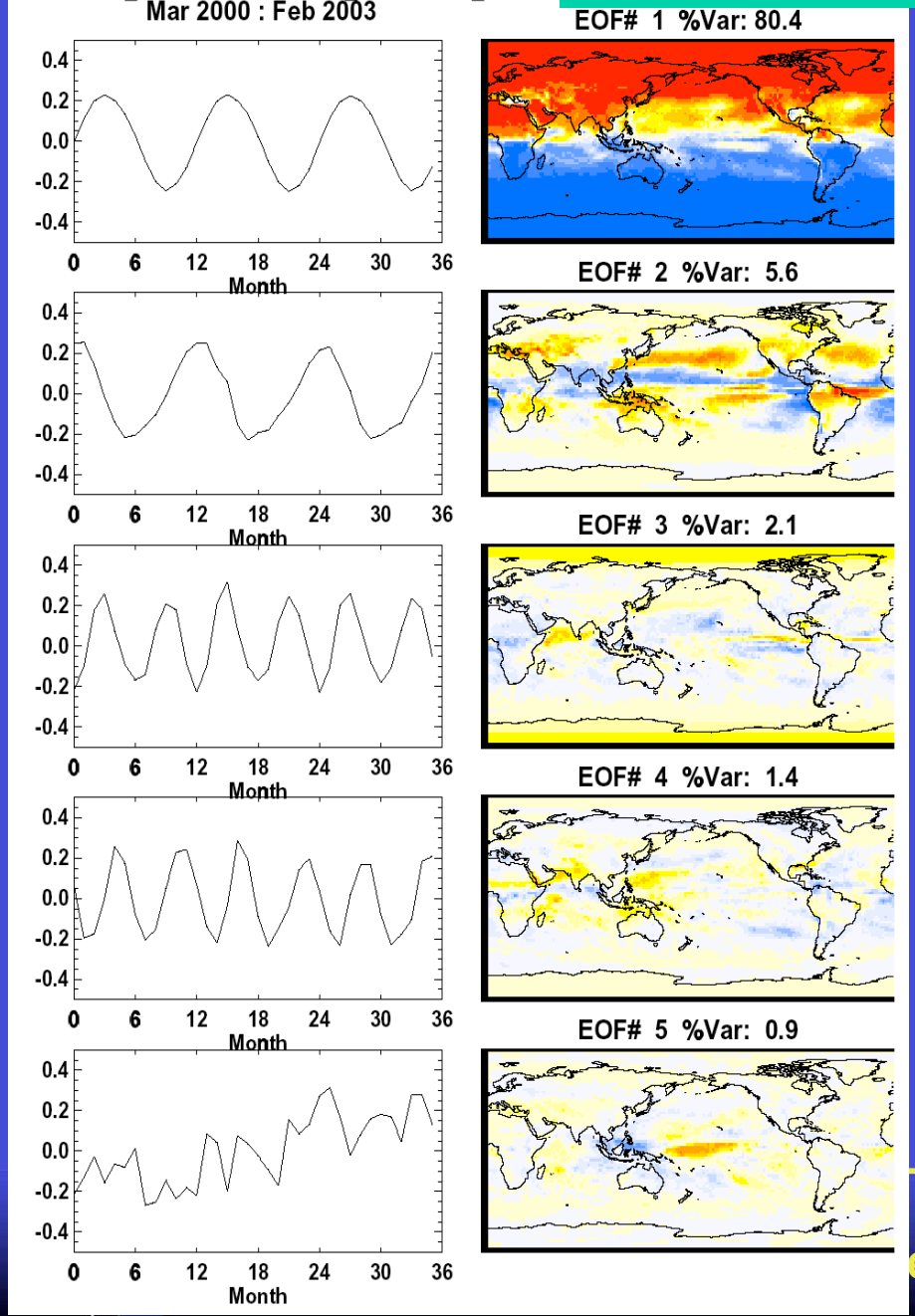
- Preliminary results show promise
- Need to further study the large SW flux scenes and LW GEO cloud emissivities
  - Evaluate GEO fluxes with MODIS clouds
  - Evaluate CERES fluxes with GEO clouds
- TISA will work with SARB to deliver SYN and AVG products in the near future

(%)	SW		LW	
	CERES	GEO	CERES	GEO
Bias	4.5	3.6	0.3	<0.1
RMS	10.8	18.0	2.5	3.6

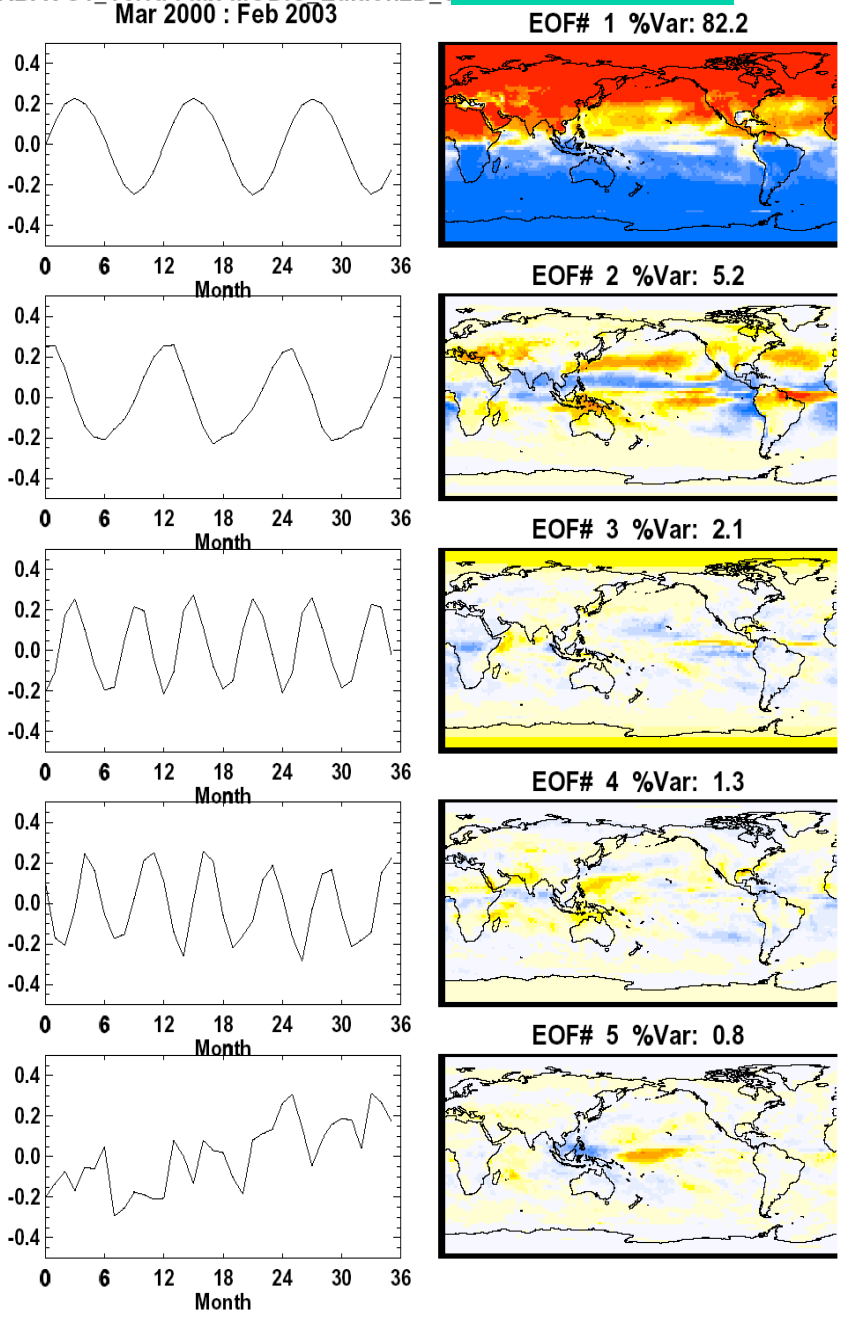
Principal Component Analysis

- Purpose
  - Test for potential GEO viewing geometry artifacts
  - Looking for “ISCCP rings”
- Method
  - Analyze TOA LW and SW Flux fields
    - (360 longitude)x(180 zones)x(36 months)
- Search for GEO artifacts in the first 10 EOF
  - Compare nonGEO with GEO

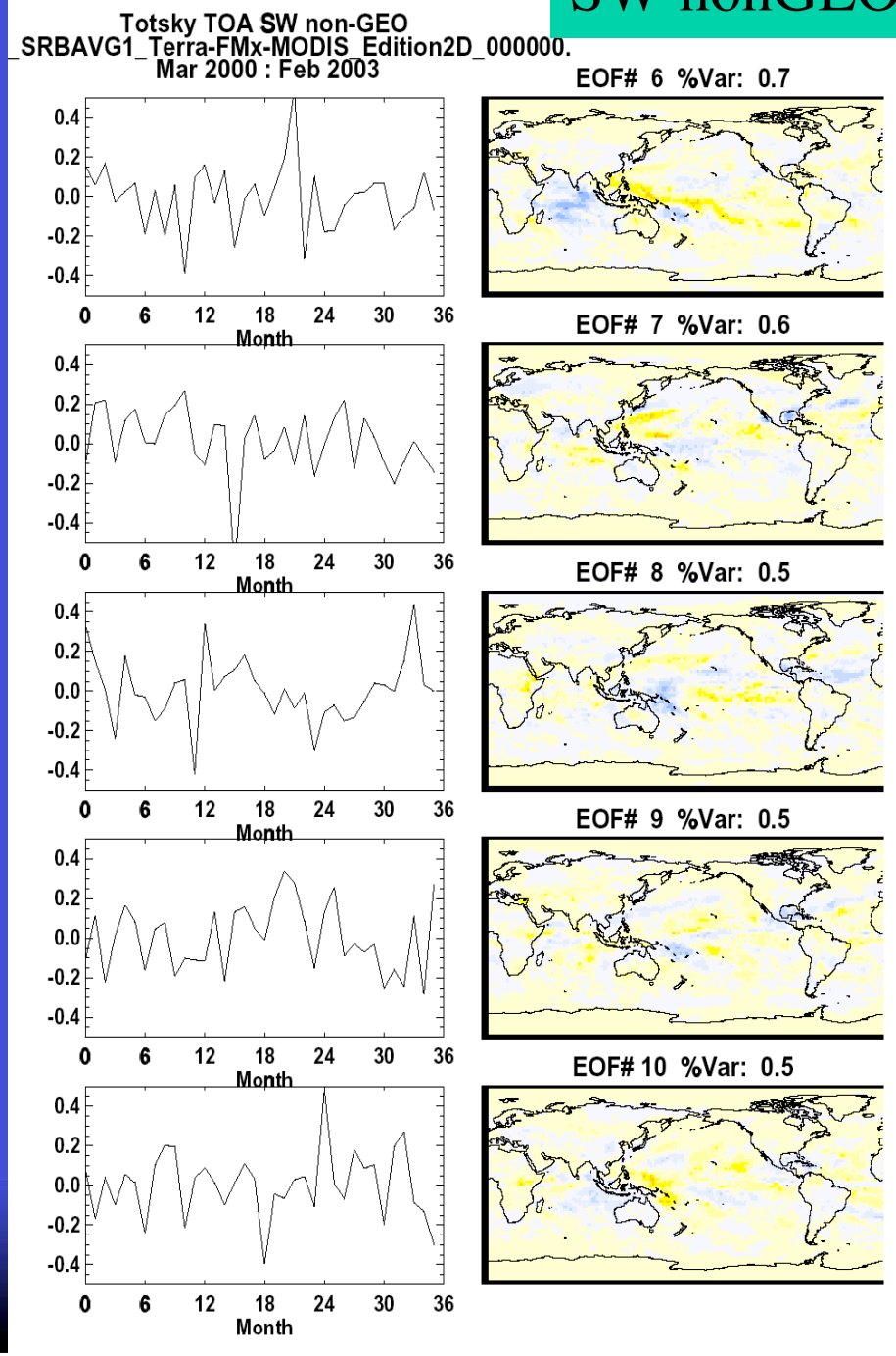
SW nonGEO



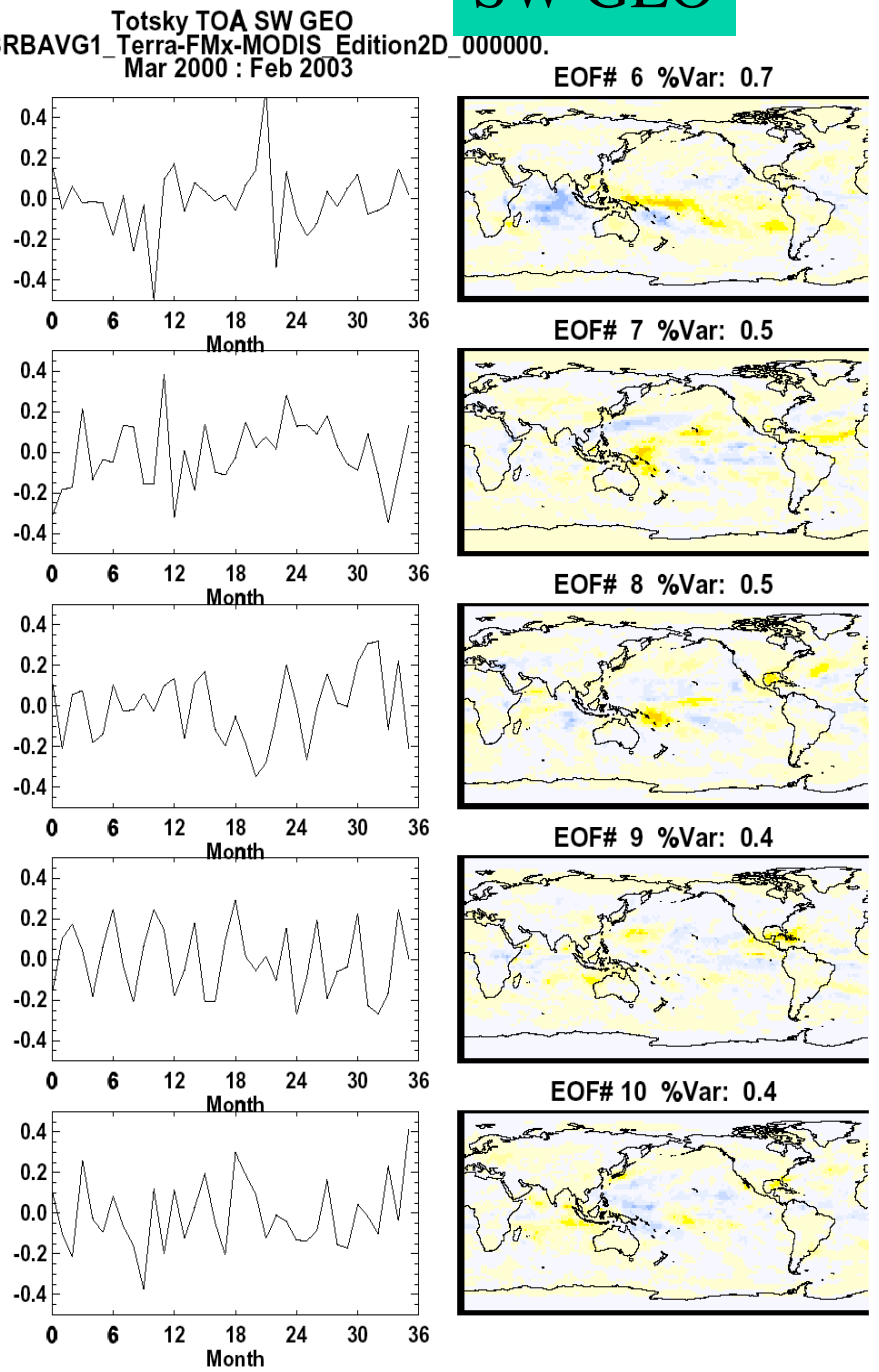
SW GEO



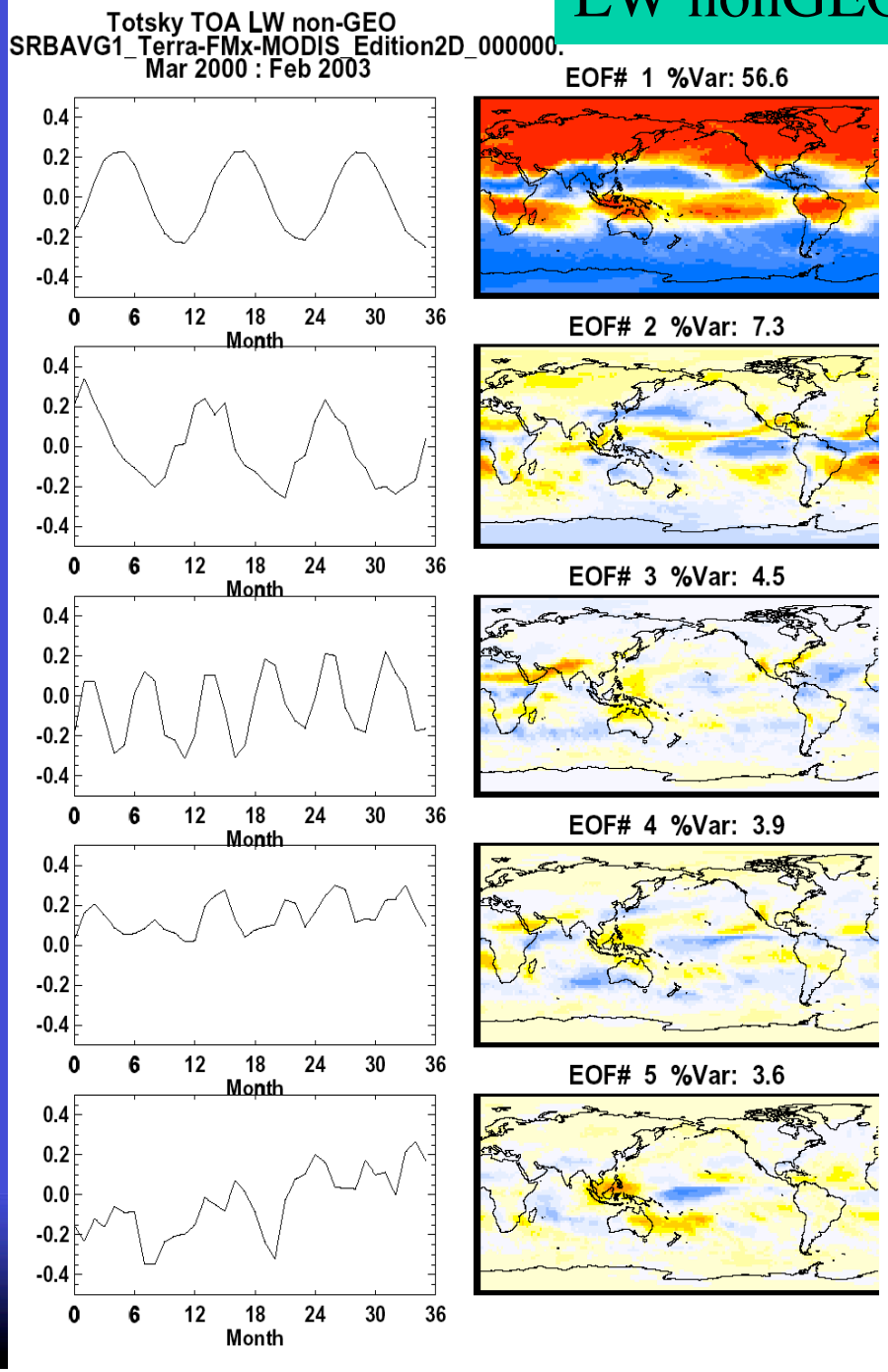
SW nonGEO



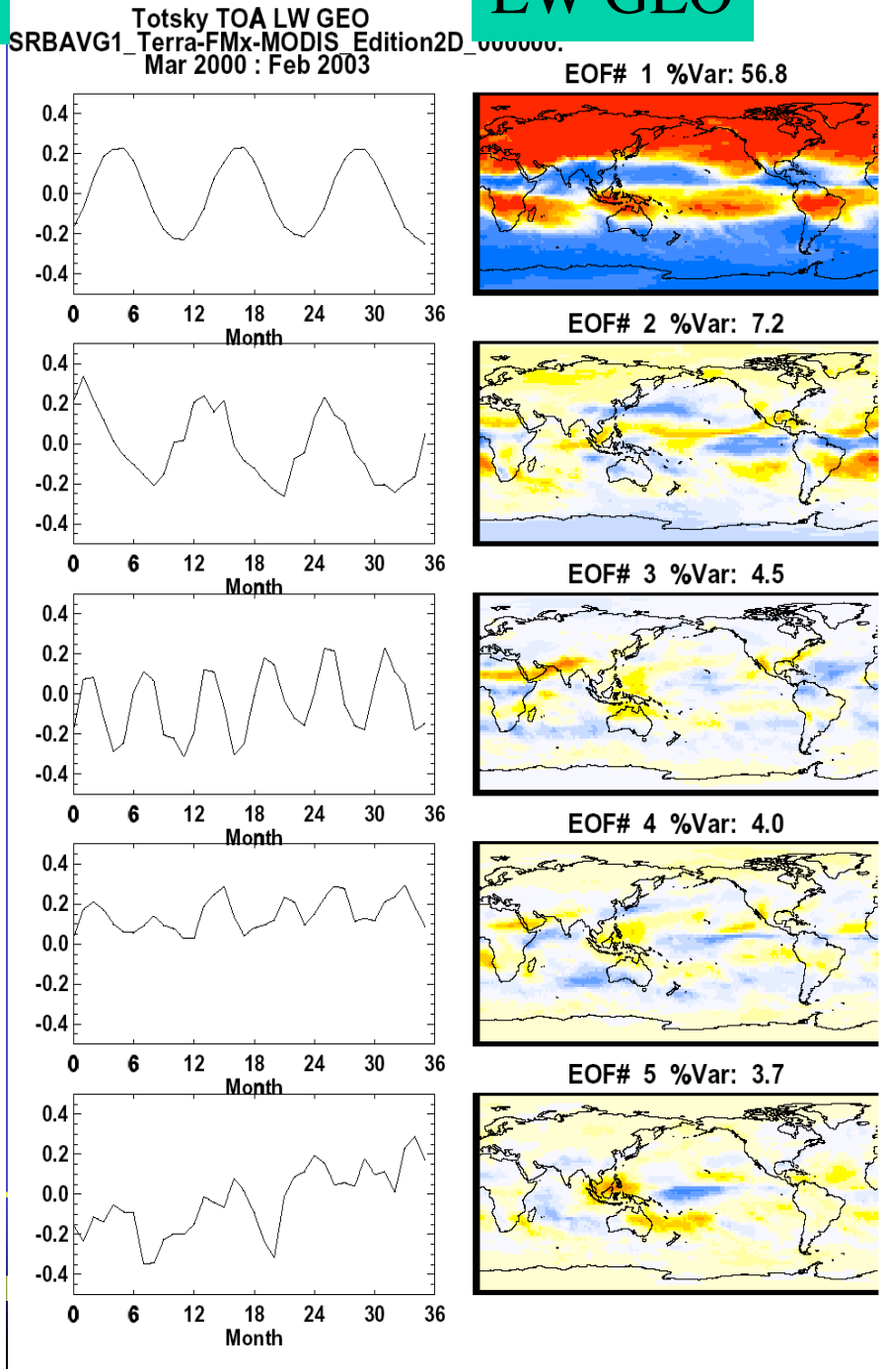
SW GEO



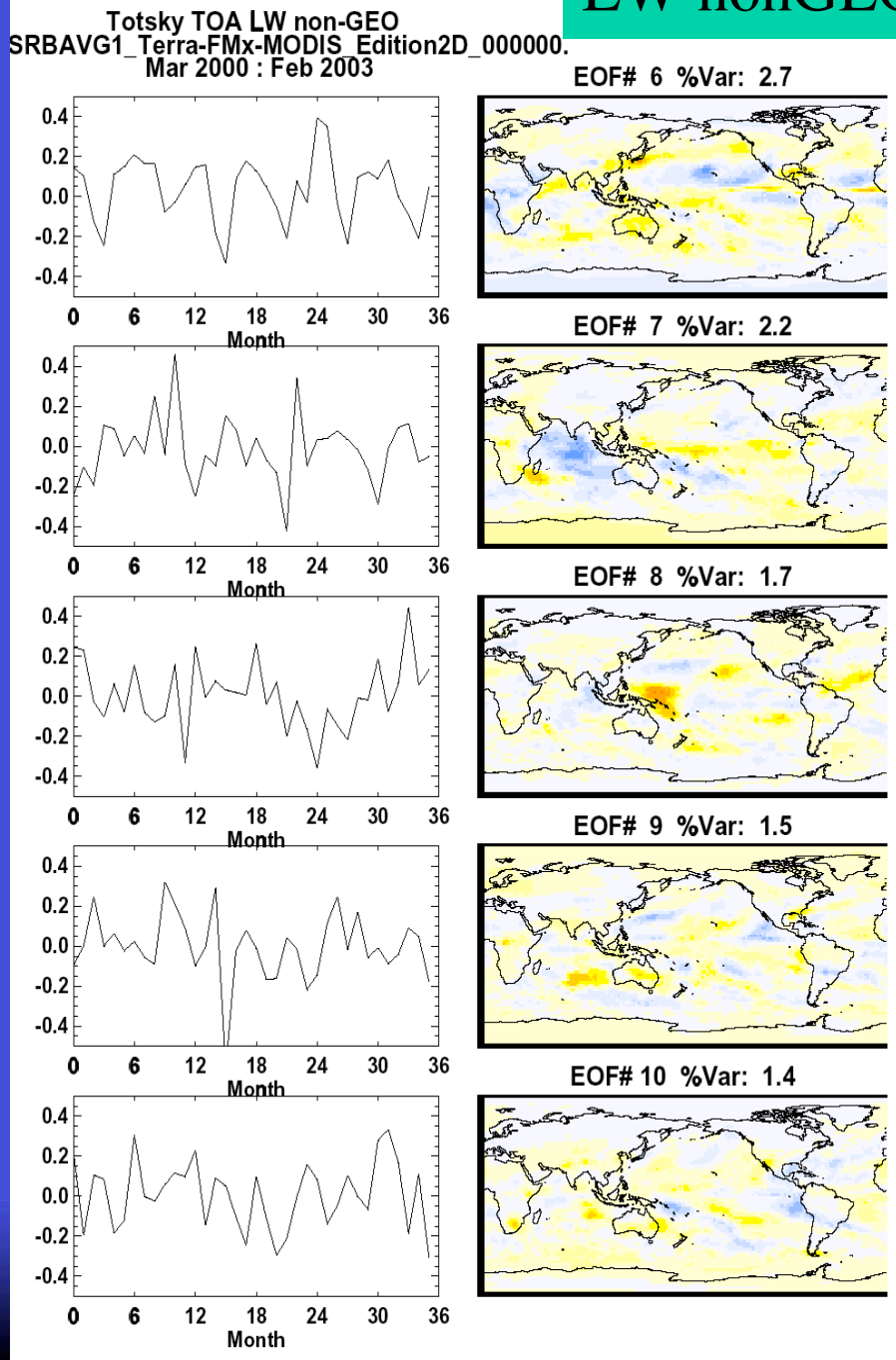
LW nonGEO



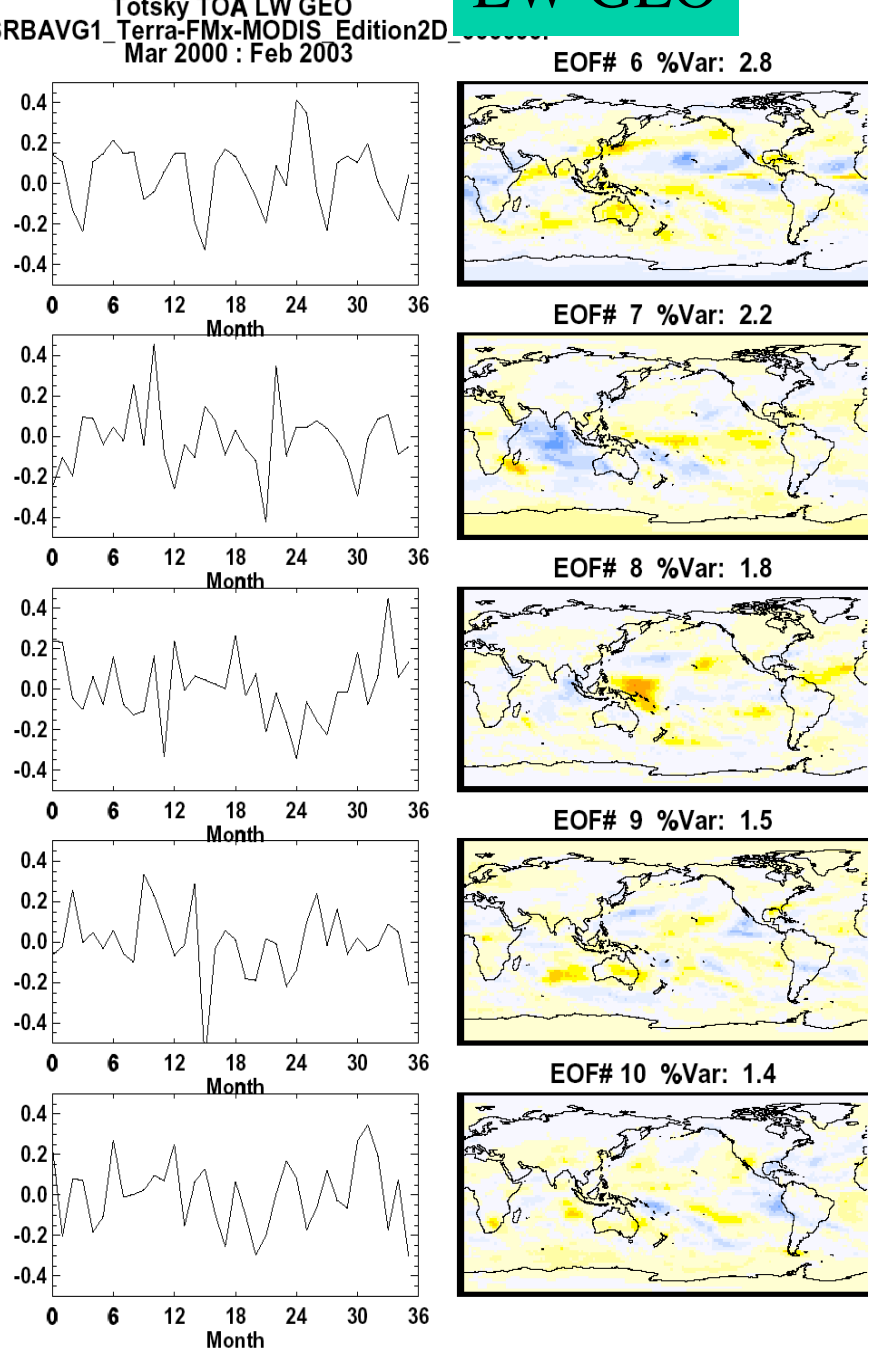
LW GEO



LW nonGEO



LW GEO



Summary of Principal Component Analysis

- No GEO artifacts observed

GEO-Derived Directional Models

- Purpose
  - Test the consistency of the sza dependence of the GEO derived albedos with the CERES-TRMM directional models
- Compared the GEO derived and CERES directional models
  - 36 months of Terra, 3-hourly, Mar00 to Feb03
- Qualitatively, the GEO directional models are in very good agreement with the CERES models after normalization
  - SZA functionality is robust across latitudes and local time
  - Ocean directional models are similar across GEO-satellites

CERES- GERB Comparisons

- Study inconclusive owing to evolving state of GERB data
  - Comparing GERB Level 2 and Terra and Aqua instantaneous fluxes
  - Comparing Version 2 and 999 GERB products
- CERES/GERB calibration and spectral correction differences remain
- GERB will ultimately provide the best independent high-resolution data set for testing the interpolation of CERES data

Summary of SRBAVG Ed 2D consistency checks

	SW		LW	
(%)	Bias	RMS	Bias	RMS
Terra-Aqua (instantaneous) (day/night)	0.3 to 0.7	15.0	0.2 to 0.7 -0.5 to –0.3	4.6 4.5
Terra-Aqua (monthly)	1.0	6.5	-0.2	1.0
Surface (monthly)	1.5	9.6	0.6	3.3
SARB (instantaneous)	3.6	18.0	<0.1	3.6
GEO Calibration(monthly)	<0.1	<1.0	<0.1	<1.0
1 vs 3 hourly(monthly)	<0.1	2.5	<0.1	0.4
EOF	No GEO artifacts			
GEO directional	Consistent with CERES			

Known Issues / Future Improvements

- GEO retrievals and data gaps
- GEO derived land OLR too cold near sunrise
- Ed 3 improvements
  - Use GEO based albedo clear-sky threshold maps
  - Constrain the GEO clear-sky ocean temperatures to be consistent with MODIS
  - MODIS/GEO cloud property normalization
  - GEO day/night cloud property normalization
  - Improved OLR and SW NB to BB
- SRBAVG products
  - Aqua+Terra
  - ISCCP-like
  - Daily means

Upcoming TISA products

- Science Team to decide whether to archive and release Edition 2d Terra SRBAVG
- If yes, then
  - Deliver final code — Nov 2005
  - Archive Mar00 to Feb03 of Terra SRBAVG — Dec 2005
  - Produce GEO calibration and clouds to Dec04 — Feb 2006
  - Archive up to Dec04 Aqua/Terra SRBAVG — Mar 2006
  - Archive up to Dec05 Aqua/Terra SRBAVG — Jul 2006
- Next Steps
  - SRBAVG-ISCCP-D2 like product — Jan 2006
  - Produce Terra Beta/Ed SYN and AVG — May/Sep 2006
  - Ed3 GEO/SRBAVG — May/Nov 2007